The role of prosody in language comprehension

When prosodic breaks and pitch accents come into play

Sara Bögels

“Practicing pronunciation without prosody is like teaching ballroom dancing-- only the students must stand still, practice without a partner, and do it all without music.” (Gilbert, 2010, p. 7).

Prosody is the music and movement of the dance of language. Prosody is also the necessary dance partner for other aspects of spoken language. Although they can dance together in several different styles, they have to move in synchrony to help listeners understand spoken language.

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Chapter 1

Introduction

Parts of this chapter are based on an invited paper in Language and Linguistics Compass: Bögels, S., Schriefers, H., Vonk, W., & Chwilla, D. J. (submitted). Prosodic breaks in sentence processing investigated by event-related potentials.

A spoken utterance is not just a string of words, but always comes with a certain intonation ('melody'), rhythm, intensity, and timing. Prosody is the collective term for these kinds of features (Ladd & Cutler, 1983). The prosody of an utterance can express various things, such as the emotional state of the speaker or whether the sentence is ironic. For example, the utterance *what nice weather* can be interpreted with opposite meanings, depending on the intonation it is pronounced with. Prosody can also help to arrive at the literal meaning of an utterance. For example, if the utterance *Peter loves Mary* is pronounced with a flat intonation, it is probably meant as a statement, whereas a rising intonation at the end of the utterance indicates it should be interpreted as a question.

The focus of the present thesis is on two different prosodic devices: prosodic breaks and pitch accents. The main question concerns how listeners process these two devices to extract information concerning the meaning of an utterance. A prosodic break (PB), also referred to as a prosodic boundary or an intonational phrase boundary, consists of a pause in a sentence, preceded by a boundary tone and a lengthening of the word before the pause (e.g., Kjelgaard & Speer, 1999). PBs often coincide with syntactic boundaries (e.g., boundaries between clauses or phrases) in a sentence, although there is no one-to-one correspondence between PBs and syntactic boundaries. If a PB coincides with a syntactic boundary, the PB can help listeners to structure the sentence syntactically. For example, the phrase *old men and women* (adapted from Beach, 1991), uttered with a PB after *men*, will be interpreted such that only the men are old: '[*old men*] [*and women*]'. In contrast, no PB (or one after old) indicates that both the men and the women are old: '[*old*] [*men and women*]'. This example demonstrates that PBs can indicate the positions of boundaries in a sentence and thereby indicate which words belong together more closely than others. Chapter 2 of this thesis mainly deals with the role of PBs in signalling syntactic boundaries and in helping listeners understand the syntactic structure of sentences.

In contrast to PBs, pitch accents make certain words in an utterance stand out. Accented words are usually produced with a higher (or lower) pitch, with a longer duration and sometimes louder than words without pitch accents. Pitch accents are thought to indicate the words that are especially relevant for sentence comprehension, because they introduce new or important information. A word can be important because it indicates a contrast that should be made by the listener. For example, if a speaker wants to refer to his car in a row of four parked cars, he has to make a contrast between his car and the other cars. If his car has a different color than the others, he could say: *The RED car is mine* (throughout this thesis, pitch accents are indicated by capital letters). In Chapter 4, we investigate how listeners process pitch accents that are used to indicate different kinds of contrast.

To summarize, PBs mainly indicate syntactic boundaries, while pitch accents emphasize words that are important or contrastive. In Chapter 3 we argue that these two prosodic devices can also work together and can both serve the function of grouping words in sentences together. The emphasis indicated by pitch accents can extend to words that are adjacent to the accented word. All words that are emphasized can then be grouped together.

The remainder of this chapter has two parts. The first part concerns the role of PBs and pitch accents in (syntactic) sentence processing and gives a preview of Chapters 2 and 3. The second part of this chapter is about the role of pitch accents in referential communication, a process in which speakers try to direct listeners' attention to an object, and gives a preview of Chapter 4.

1.1 Prosodic breaks and pitch accents in sentence processing

1.1.1 Background to the study of sentence processing

Before we turn to the role of prosodic cues in sentence processing, we first briefly review how sentence processing has been investigated and what kinds of factors have been found to affect this process.

Ambiguous sentences. To investigate sentence processing, researchers have made extensive use of ambiguous sentences. Globally ambiguous sentences or phrases, like the example above (*old men and women*) are not disambiguated by the words at any position in the sentence. In contrast, locally ambiguous sentences are only ambiguous up to a certain point in the sentence at which the ambiguity is resolved. As an example, in (1) the ambiguous part of such a sentence is given; this part could be interpreted such that the man has been playing a tape, or that the tape has been played to the man by someone else. The former interpretation corresponds to the disambiguating continuation in (a) and the latter to the continuation in (b).

1. The man played the tape…
    a. …and liked it.
    b. …liked it.

Syntax first. Syntax first models make two basic assumptions. First, in (locally) ambiguous sentences, listeners pursue only one of the possible structures. Second, this structure is generated purely on the basis of syntactic principles (for a review see Townsend & Bever, 2001). According to the Garden Path Theory (Frazier & Fodor, 1978; Frazier & Rayner, 1982), two syntactic principles determine the initial parsing of a sentence. If this initial parsing turns out to be incorrect, one is *led down the garden path* and should reanalyze the sentence. The principle of *minimal attachment* states that a sentence is parsed in such a way that the minimal amount of nodes is used in a syntactic tree. For (1), this principle would predict the continuation in (a), rather than (b), since the syntactic tree of (1a) has less nodes than that of (1b) (see Figure 1.1).

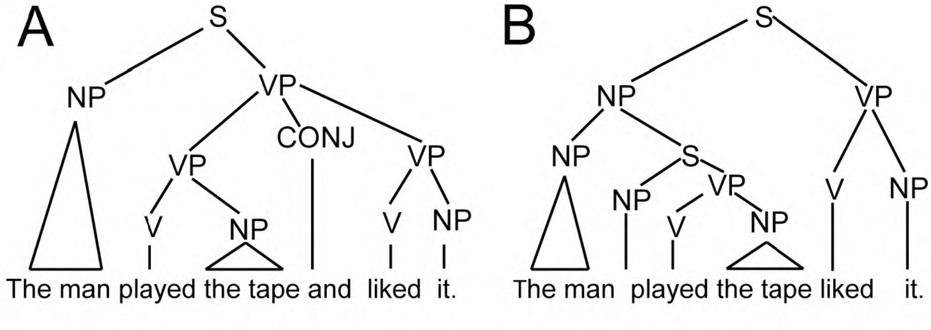

Figure 1.1 Syntactic trees for (1a) and (1b). The structure in (1a) (panel A) has fewer nodes than the structure in (1b) (panel B) and is thus preferred according to the principle of minimal attachment (adapted from Ferreira & Clifton, 1986).

Ferreira and Clifton (1986) found support for this principle in that participants took longer to read sentences like (1b) as compared to their unambiguous counterparts (*The man that was played the tape*...), which was not the case for sentences like (1a).

According to the principle of *late closure*, the current syntactic clause should be closed as late as possible. Thus, new constituents should always be interpreted as part of the current clause, if possible.

2. Since Ray always jogs a mile…
   a. …this seems like a short distance to him.
   b. …seems like a short distance to him.

For the locally ambiguous sentence in (2), late closure would predict continuation (a) because this corresponds to an interpretation in which *a mile* is incorporated as direct object of *jogs*. In contrast, for the interpretation in (2b), *a mile* is the subject of a new sentence. Frazier and Rayner (1982) indeed found longer reading times for continuations like (2b) than for continuations like (2a).

Semantic and discourse factors. As a challenge to syntax first models, later studies found evidence that other factors than syntactic principles can also affect the initial parsing of a sentence. For example, Hoeks, Hendriks, Vonk, Brown, and Hagoort (2006) showed that a semantic factor could make early closure sentences easier to process.

3. The sheriff protected the farmer and the farm hand…
   a. …in front of the shed.
   b. …defended the ranch.
4. Jasper sands the board and the carpenter scrapes the paint from the doors.

In (3) (from Kerkhofs, Vonk, Schriefers, & Chwilla; 2008; English translation of originally Dutch item), the late closure principle would predict that *the farmer* is attached to *the farm hand* (NP-coordination) and that together they are the object of *protected*, as in (3a). In contrast, (3b), in which *the farmer* starts a new sentence (sentence-coordination), would lead one down the garden path. Hoeks et al. (2006) also looked at sentences like (4), with the same syntactic structure as (3b). However, since the verb *sand* usually does not take an animate object, an NP-coordination (in which *the carpenter* would be the object of *sands*) is very unlikely. Less processing difficulty was found for sentences like (4) relative to unambiguous sentences (disambiguated with a comma after *board*), than for sentences like (3b). Other studies have shown effects of semantic fit of nouns to an argument position (e.g., Mak, Vonk, & Schriefers, 2002; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Trueswell, Tanenhaus, & Garnsey, 1994) and effects of verb biases towards a certain (argument) structure on sentence processing (e.g., Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Itzhak, Pauker, Drury, Baum, & Steinhauer, 2010; Trueswell, Tanenhaus, & Kello, 1993).

With the same type of sentences as in (3), Hoeks, Vonk, and Schriefers, (2002) showed that discourse context can also play a role. If (3b) was embedded in a context with two topics, *the sheriff* and *the farm hand*, it became much easier to process than when presented in isolation (see also e.g., Altmann & Steedman, 1988; Spivey-Knowlton, Trueswell, & Tanenhaus, 1993). Such effects of semantic and discourse factors on syntactic parsing provide support for interactive, constraint-based theories (see Townsend & Bever, 2001 for a review). According to these theories, different factors interact and provide support for a certain parsing. The parsing that receives the most support from different factors is chosen.

For a long time, researchers have focused primarily on visual sentence processing, that is, reading studies. In spoken language processing, prosody might provide a very helpful additional source of information. In particular, prosodic breaks can provide useful information about syntactic breaks. However, to study auditory sentence processing, different methods are needed.

1.1.2 How to study prosodic breaks in sentence processing

Off-line studies. Studies on the role of PBs in auditory sentence processing have also made use of ambiguous sentences. An example of a globally ambiguous sentence, used in a study by Schafer (1995), is given in (5) (# stands for PB).

5. Paula phoned ($\#^1$) her friend ($\#^2$) from Alabama.

In this study, participants listened to sentences like (5) with a PB at one of two positions (indicated by $\#^1$ and $\#^2$). Then, they had to choose between the two possible interpretations of the sentence ('the friend is from Alabama' or 'Paula phoned from Alabama'; where $\#^1$ matches the first interpretation and $\#^2$ the second). It was found that the position of the PB affected the participants' choice (see also e.g., Streeter, 1978). Other studies used locally ambiguous sentences such as (6) (from Beach, 1991).

6. Mary suspected (#) her boyfriend…
    a. …immediately.
    b. …was lying.

By manipulating the length and the boundary tone of the word *suspected*, Beach (1991) created versions of (6) with and without a PB. Participants were presented with the two versions of sentences like (6), and then had to choose between the two possible endings (a) and (b). Participants more often chose (a) in the absence of a PB and (b) in the presence of one (see also Stirling & Wales, 1996). Given that these studies use off-line measures, they do not tell us whether listeners use the prosodic cues immediately during on-line processing of the sentence.

On-line studies. To investigate the on-line use of PBs during sentence comprehension, researchers have turned to on-line tasks, like cross-modal naming or cross-modal lexical decision. For example, Kjelgaard and Speer (1999) presented participants with the beginning of locally ambiguous sentences like (7), which can be disambiguated as in (a) or as in (b).

7. When Roger leaves ($\#^1$) the house ($\#^2$) …
    a. …is dark.
    b. …it's dark.

Immediately after hearing the ambiguous part, listeners had to name a visually presented word (cross-modal naming) which was the first word of either continuation (a), fitting the ambiguous part with $\#^1$ after *leave*, or continuation (b), fitting the ambiguous part with $\#^2$ after *house*. Words that fitted the prosody of the sentence beginning were named faster than those that did not (see also Marslen-Wilson, Tyler, Warren, Grenier, & Lee, 1992; Warren, Grabe, & Nolan, 1995 for similar results; but see Watt & Murray, 1996). Although these studies demonstrate on-line effects of PBs on sentence comprehension, they use rather artificial tasks; participants are asked to listen to sentence fragments and then to perform a naming task or a lexical decision task on a visually presented continuation of the sentence.

A study by Sanderman and Collier (1997) also looked at the role of prosodic phrasing in sentence comprehension. They presented participants with globally ambiguous Dutch sentences (the English translation of an example item is given in (9)) that were synthesized to have a prosody supporting either of the two interpretations or to have a neutral prosody (without PBs). Each of these auditory sentences was preceded by a written question like (8), biasing one of the two interpretations.

8. a. How did I reserve a room?
   b. Which facility did the hotel have?
9. I reserved a room ($\#^1$) in a hotel ($\#^2$) with the fax…

Question (8a) biases towards the interpretation that the room was reserved by means of the fax and should thus match the prosody in which a PB is present after hotel ($\#^2$). In contrast, question (8b) biases towards the interpretation that the hotel has a fax, matching the prosody with a PB after room ($\#^1$). Participants were instructed to monitor for the word that provides an answer to the question (*fax*) and had to press a button as soon as they new the answer. It was shown that listeners were faster to recognize the correct word when the prosody matched the interpretation induced by the question, than in the case of a mismatching or neutral prosody. For reviews of off- and on-line studies on the role of PBs in sentence processing see Carlson (2009) and Cutler, Dahan, and Van Donselaar (1997).

ERP studies. In the visual modality, self-paced reading or eye-tracking are often used to investigate on-line sentence processing. Unfortunately, no equivalent of these methods is available in the auditory modality. However, Event-Related Potentials (ERPs) provide a way to avoid many of the problems of the on- and off-line methods mentioned above.

ERPs are extracted from the electroencephalogram (EEG). The EEG is the electrical activity from the brain that can be measured by electrodes attached on the scalp. It reflects the activity of large populations of neurons, mostly in the cerebral cortex, that fire synchronously. The EEG at a single position on the scalp is measured differentially with respect to the activity at reference electrodes. These reference electrodes are usually located behind the left and right ear (mastoids), since these locations are considered to be unaffected by brain activity. Since eye-movements can greatly distort the EEG, the EOG (electrooculogram) is recorded during the EEG measurement to be able to remove later any trials contaminated with horizontal and vertical eye-movements or eye blinks. To keep these removed trials to a minimum, subjects are often instructed to refrain from blinking and moving their eyes during critical moments in the recording (e.g., presentation of a sentence).

From the EEG, event-related potentials (ERPs) can be extracted, which are related to an 'event' of interest, such as a specific stimulus. Since ERPs are generally much smaller than the background EEG, they are not visible in the raw EEG. To extract ERPs, small epochs of the EEG (usually around one second) are cut out around an event or stimulus of interest, for example, the critical word in a sentence. These epochs are time-locked to the stimulus, usually to its onset. Generally, a time window before this time-locking point is also extracted to serve as a baseline. The EEG within this baseline is set to zero, to remove any differences between stimuli that might exist before the onset of the stimulus of interest. Then, all epochs that contain artifacts (such as eye-blinks or other muscle artifacts) are removed and finally all epochs of the same condition are averaged. By this averaging procedure, the parts of the EEG that are unrelated to the stimulus are averaged out, whereas parts related to the stimulus remain. Usually, these averages are computed per participant and then enter statistical analyses in which ERPs from different conditions are compared.

ERPs are especially well-suited to investigate spoken sentence processing, since they provide a measure of processing across the sentence as it unfolds in real time. Therefore, complete sentences can be presented continuously and participants (ideally) do nothing else than listen for comprehension, as they do in daily life. However, although no additional task is needed when using ERPs as a dependent measure, in many ERP studies, participants nevertheless perform some additional task. We will come back to this issue later.

1.1.3 First ERP study on prosodic breaks in sentence processing

Steinhauer, Alter, and Friederici (1999) used ERPs to investigate the on-line processing of locally ambiguous sentences which can be disambiguated by a PB. Participants listened to German sentences such as (8), (9), and (10).

8. Peter verspricht Anna zu arbeiten…
   Peter promises Anna to work… (literal translation/paraphrase)
9. Peter verspricht # Anna zu entlasten…
   Peter promises Anna to support… (literal translation)
   Peter promises to support Anna… (paraphrase)
10. Peter verspricht # Anna zu arbeiten…
   Peter promises Anna to work… (literal translation/paraphrase)

In German, in contrast to English, these sentences have the same word order and they are only disambiguated by the second verb (*arbeiten/entlasten*). In (8) this verb (*arbeiten*, 'to work') is intransitive and thus cannot take *Anna* as its (direct) object. Therefore, *Anna* has to be interpreted as the indirect object of the first verb (*verspricht*, 'promises'). In contrast, in (9) the second verb (*entlasten*, 'to support') is obligatorily transitive such that *Anna* has to be the direct object of *entlasten*, and thus cannot be the indirect object of *verspricht*. Steinhauer et al. (1999) assumed that for these types of sentences, the initial preference would be for the structure in (8), which would be expected based on the minimal attachment principle (Steinhauer, 2003) and the late closure principle.

Steinhauer et al. (1999) hypothesized that prosody would have the following effect on the processing of these sentences. A PB after *verspricht* disambiguates the sentence towards an interpretation in which *Anna* is not the indirect object of *verspricht* (as in 9) and thus leads to processing problems when the sentence is continued with an intransitive verb (*arbeiten*, 'to work'), as in (10). The intransitive disambiguating verb *arbeiten* in (10) elicited an N400 and a P600 component in the ERP as compared to the transitive verb *entlasten* in (9). The N400 (Kutas & Hillyard 1984) is a negative peak in the ERP around 400 ms after onset of the critical word (i.e., the second verb) and its amplitude varies as a function of how well a word fits in a context (for example, in the sentence *He spread the warm bread with…*, a continuation with the word *socks* elicits a much larger N400 than a continuation with the word *butter*; see Kutas, Van Petten, & Kluender, 2006 for a review). Steinhauer et al. interpreted the N400 as a reflection of lexical re-access to confirm the violation of the intransitive argument structure of the verb *arbeiten*. The P600, a positive wave starting around 600 ms after onset of the critical word, is reliably elicited by syntactic violations and by unexpected disambiguations of locally ambiguous sentences (e.g., Osterhout, Holcomb, & Swinney, 1994). Steinhauer et al. regarded it as an indication of structural revision, in which *Anna* has to be attached to a different verb. Although the precise functional significance of the P600 is currently under debate (e.g., Friederici, 2002; Kuperberg, 2007; Van de Meerendonk, Chwilla, Kolk, & Vissers, 2009), the N400 and P600 on the intransitive disambiguating verb (*arbeiten*) show that PBs can affect the syntactic analysis that listeners pursue.

Steinhauer et al. (1999) also compared sentences (8) and (10), which contain the same words, but differ in the presence versus absence of a PB. For sentences such as (10), which contain a PB, they found a new ERP component at the position of the PB. This component is related to the processing of the PB itself. They termed it the Closure Positive Shift (CPS), since it took the form of a positive shift at the closure of an intonational phrase.

The Steinhauer et al. (1999) study provided two important insights. First, the use of ERPs makes it possible to study the processing of the PB itself. Steinhauer et al. discovered that a PB elicits a CPS, which they related to prosodic processing. Second, Steinhauer et al. also showed that PBs can have an effect on syntactic processing. This is in line with the behavioural on- and off-line studies reported above. However, ERPs make it possible to study the role of prosody in sentence processing in a more natural situation, that is, with complete and continuously presented spoken sentences. Both insights have triggered a lot of follow-up research. In the following, we will first discuss the relevant evidence on the processing of the PB itself, that is, the evidence concerning the CPS. Then we will turn to evidence concerning the role of PBs in arriving at the eventual interpretation of a sentence.

1.1.4 The Closure Positive Shift

Profile of the CPS. Since its discovery in 1999 by Steinhauer et al., the finding of a CPS at the PB itself has been replicated in several languages such as German (e.g., Isel, Alter, & Friederici, 2005), Dutch (Kerkhofs, Vonk, Schriefers, & Chwilla, 2007; 2008), English (Pauker, Itzhak, Baum, & Steinhauer, submitted), Japanese (Wolff, Schlesewsky, Hirotani, & Bornkessel-Schlesewsky, 2008), and Chinese (Liu, Jin, Li, Li, & Wang, 2009). These studies lead to the following general profile of the CPS. In terms of scalp distribution, the CPS is found bilaterally and is most prominent at midline electrodes. Steinhauer et al. found a centroparietal distribution, but some studies report an extension to anterior electrodes (e.g., Pannekamp, Toepel, Alter, Hahne, & Friederici, 2005). The CPS generally starts around or even before pause onset (Steinhauer, 2003). Its offset appears to be triggered by the onset of the word after the pause (Pauker et al., submitted). Finally, some studies have reported a small negativity preceding the CPS (e.g., Kerkhofs et al., 2007; Pannekamp et al., 2005; Pauker et al., submitted).

Scope of the CPS. How can one establish that the CPS is specifically responsive to PBs? Several alternative accounts have been refuted. First, Steinhauer (2003) argues against an interpretation of the CPS as an average of spread-out P2 components in response to the onset of the word after the pause. In particular, he proposes that this is very unlikely since the CPS starts well before the average pause offset. Moreover, a low-pass filtering of 1 Hz led to a disappearance of P2 components elicited by sentence onset, while the CPS remained present. Second, despite a correspondence in polarity, the CPS does not seem to be a variety of the P600, because the CPS is elicited in correct and unambiguous sentences. However, it is possible that the CPS and the P600 share common sub-processes (Steinhauer & Friederici, 2001). Third, Steinhauer et al. (1999) showed that the CPS is not just a response to the pause in the speech signal. When they removed the pause, while keeping the other features of the PB (prefinal lengthening and boundary tone) intact, a CPS was still observed.

Several follow-up studies on the CPS have extended the scope of this ERP component. First, Pannekamp et al. (2005) showed that a CPS is a purely prosodic component, as a CPS in response to a PB also occurs in jabberwocky sentences (with pseudo content-words, preserving syntax), pseudo sentences (exclusively pseudo words and no semantics or syntax) and even in hummed ‘sentences’ without any phonological-segmental content. The CPS has a more anterior and right distribution for sentences with less linguistic content. Second, a CPS was also elicited by breaks that indicate phrasing in music (Knösche et al., 2005). Follow-up studies showed that western and non-western musicians show a music CPS (Nan, Knösche, & Friederici, 2006). Whether a music CPS can also be shown for non-musicians is controversial (Nan, Knösche, & Friederici, 2009; Neuhaus, Knösche, & Friederici, 2006). The music CPS appears to occur later than the linguistic CPS, possibly because the perception of a boundary in music requires more contextual information (Pauker et al., submitted). Third, a (small) CPS has also been found in response to a comma in written sentences in German and Chinese (Steinhauer & Friederici, 2001; Liu et al., 2010), suggesting that commas can have the same function in reading as PBs in listening. The visual CPS can be interpreted as some kind of visual phrasing or as reflecting subvocal prosodic phrasing, which is triggered by the comma (Steinhauer, 2003; Steinhauer & Friederici, 2001). This ‘visual’ CPS was only elicited for participants with strict punctuation habits. Kerkhofs et al. (2008) did not replicate the CPS in response to a comma in Dutch, possibly because Dutch has less strict punctuation rules than German. Fourth, there has been some debate about the age at which the CPS can be observed in children. Pannekamp et al. (2006) reported a CPS for 8-month-old infants. In contrast, for 5-month-olds, Männel and Friederici (2009a) found only obligatory components (cf. N1-P2 components), signalling lower-level perceptual processing of acoustic cues. These components disappeared when the pause was removed from the speech signal. Recent studies from the same laboratory found a CPS in children only from about 3 years of age (Männel &

Friederici, 2009b), suggesting that syntactic knowledge seems to affect the development of prosodic phrasing. Fifth, despite the fact that elderly listeners often show a reduction in speech processing abilities, in older adults (65-80 years of age) a normal CPS is elicited (Steinhauer, Abada, Pauker, Itzhak, & Baum, 2010). Sixth, in question-answer pairs, a CPS appears also to be elicited by new information (Hruska & Alter, 2004; Toepel, Pannekamp, & Alter, 2007). These authors argue that those elements that are important for structuring the utterance are the elicitors for the CPS.

Taken together, the available evidence strongly suggests that the CPS reflects some kind of structuring of the input. Whether this structuring is specific to the auditory modality or whether it is modality independent needs further investigation. However, it is clear that the CPS is not just a response to low level (acoustic-phonetic) cues of PBs. Rather, the CPS reflects structuring based on (the integration of) several cues, which might be different for different domains such as music and language.

Size of the CPS. A related point concerns the factors determining the size of the CPS. Steinhauer (2003) argues that the CPS amplitude depends on the amount of activation of phonological representations in the brain. He reports a smaller CPS for covert prosodic phrasing, either in reading a comma, or in applying a de-lexicalized intonation contour to a written sentence. Kerkhofs et al. (2008) propose that the size of the CPS depends on the salience of prosodic boundary markers. A comma might be less salient than a PB in a language with lax punctuation rules (like Dutch), leading to a reduction or the absence of a CPS in response to a comma. Also, a larger CPS is elicited by a less expected PB, which is therefore more salient (Kerkhofs et al., 2007; see below).

How to analyze the CPS. From the above, we can conclude that the CPS appears to be a response to the PB as a whole. However, it remains unclear which aspects of the PB are necessary for the elicitation of a CPS. Since the pause is apparently not necessary, the prefinal lengthening and/or boundary tone remain viable candidates for bringing about the CPS. As the precise elicitors of the CPS are still unclear, it is hard to determine the appropriate time-locking point to compute ERPs to obtain a CPS. Different time-locking procedures have been used in past research (e.g., Steinhauer et al., 1999; Kerkhofs et al., 2007). In Chapter 2 we compare different time-locking procedures and aim to determine an objective 'onset of the PB' as a potentially more appropriate time-locking point.

1.1.5 The role of PBs in sentence processing

The study by Steinhauer et al. (1999) was followed up by other studies on the role of PBs in sentence processing. Kerkhofs et al. (2008) used the Dutch items that were already used by Hoeks et al. (2002) of which an example was given in (3), here repeated as (11).

11. The sheriff protected the farmer (#) and the farm hand…
    a. …in front of the shed.
    b. …defended the ranch.

As described above, Hoeks et al. (2002) had shown that the general parsing preference for these sentences (if no semantic or discourse factors play a role) is NP-coordination, as in (11a). Kerkhofs et al. (2008) hypothesized that, for spoken sentences, a PB after *the farmer* would reverse this preference to sentence-coordination, as in (11b). They presented participants with spoken sentences like (11b), with or without a PB after *the farmer*. The disambiguating verb (*defended*) for sentences without a PB as compared to sentences with a PB elicited typical reflections of processing difficulty: a P600 or a left-anterior negativity (LAN: an ERP component elicited for example by word category violations; Friederici, 1995). Apparently, the PB changed the parsing preference from a preference for an NP-coordination to a preference for a sentence-coordination.

Wolff et al. (2008) investigated the role of PBs in Japanese. Japanese has a relatively free word order and uses case marking to identify, for example, subjects and objects. A PB after the first NP of a sentence indicates word order scrambling, that is, a word order that deviates from the canonical subject-object-verb order. Wolff et al. compared sentences starting with either a (case-marked) object NP or a (case-marked) subject NP. The initial object NP (as compared to the initial subject NP) elicited a negativity in the ERPs indicating word order scrambling, but only when the initial NP was followed by a PB. In contrast, in the absence of a PB, no negativity occurred. The authors took this finding to indicate that listeners expected a simpler structure with only an object (which is acceptable in Japanese because the subject can be dropped).

Pauker et al. (submitted) tested the role of PBs in English locally ambiguous sentences, such as (12) and (13).

12. When a bear is approaching the people # the dogs come running.
13. When a bear is approaching # the people come running.

Without PBs, early closure sentences like (13) are more difficult to understand than late closure sentences like (12) (as predicted by the late closure principle described above; Frazier & Rayner, 1982). In (12) and (13), the position of the PBs is in line with the eventual disambiguation of the sentences. In addition, there were two mismatching conditions: for (12), this condition had an additional (superfluous) PB after *approaching,* and for (13), this condition had no PB at all, that is, a condition with a missing PB. For sentences with a superfluous PB, a biphasic N400/P600 pattern was found at the second PB, while sentences with a missing PB only gave rise to a small P600 at the disambiguation (*come*). The authors concluded that a superfluous PB is more difficult to process than a missing PB (see below). For the same type of sentences, Itzhak et al. (2010) showed that a correctly placed PB as in (13) can override both the general parsing preference and a verb bias towards a late-closure interpretation.

Mietz, Toepel, Ischebeck, and Alter (2008) studied mismatches between PBs and other aspects of sentence prosody in German sentences; see the English translations in (14) to (16).

14. Anton bites # Patricia squeals and Carola lies. (correct condition)
15. Anton bites # Patricia. (infrequent condition: *vocative*; i.e., explicitly addressing Patricia)
16. Anton bites # Patricia and Carola lies. (violation condition)

Sentence (16) was created by cross-splicing the first part of (14) (*Anton bites #*) with the second part of a sentence like *Anton bites Patricia and Carola lies.* As a result, (14) to (16) differ with respect to the match between the PB and the prosody of *Patricia*. In (16), the prosody of Patricia does not match the prosody to be expected on the basis of the preceding PB, while in (14) it does. The ERPs time-locked to *Patricia* revealed, relative to the correct condition (14), a biphasic N400/P600 pattern in (16), but a monophasic N400 effect in the infrequent (vocative) condition (15).

The studies described above looked at the effect of a PB later in the sentence. In contrast, Kerkhofs et al. (2007) investigated whether syntactic and prosodic information are matched immediately. They used sentences like (11a) and (11b) above and induced the expectation of a syntactic break at the position of the PB (after *farmer*). To induce this expectation, they used the result from Hoeks et al. (2002) that a discourse context with a dual topic structure leads to the expectation of two topics (e.g., *the sheriff* and *the farm hand*) and thus to the expectation of sentence-coordination as in (11b). Thus, the exact same sentences (like 11b), with a PB, were placed in a preceding neutral context (creating the default expectation for one topic) versus a dual topic context. The PB elicited a larger CPS when it was unexpected (in the neutral context) as compared to when it was expected based on the dual topic context.

1.1.6 Preview of Chapters 2 and 3

As described above, Steinhauer et al. (1999) showed an effect of a PB at the disambiguating verb of their experimental sentences (see (8) to (10) above). A disambiguating intransitive verb that did not fit the presence of a PB in the sentence (*arbeiten* in (6)) led to a biphasic N400/P600 pattern relative to a transitive verb that did fit the presence of a PB (*entlasten* in (5)). However, this study has a number of methodological drawbacks.

First, these authors did not establish the general parsing preference for the constructions they used in the absence of relevant prosodic cues (and this preference had not been established in earlier studies). According to both the principles of minimal attachment (Steinhauer, 2003) and late closure (Pauker et al., submitted; Steinhauer, personal communication), *Anna* would be regarded as the indirect object of *verspricht*, leading to a parsing such as in (8). For this reason, Steinhauer et al. (1999) assumed that the general parsing preference would lead to a preference for an intransitive verb. However, as shown by the studies described above (e.g., Hoeks et al., 2002; 2006) syntax first principles are not the only factors that determine a parsing preference in the absence of specific prosodic cues. Thus, it is uncertain whether Steinhauer et al.'s assumption was correct. Because the general parsing preference of these sentences is unknown, the results of Steinhauer et al. cannot tell us whether the PB changed this preference in any way. In Chapter 2, we investigate the general parsing preference of these sentences without a PB in two different ways: we perform an off-line fragment completion study, to get a first indication of the general parsing preference for these sentences and we conduct an ERP study with a full design (in contrast to Steinhauer et al.), presenting participants with versions of sentences such as (8) and (9) both with and without a PB after the first verb. By comparing the sentences without a PB, we can determine the on-line parsing preference of these sentences without a PB and compare that to the preference for the same sentences with a PB.

Second, regarding the materials of Steinhauer et al. (1999) (Steinhauer, personal communication), all the experimental sentences superficially seem to have a similar structure.

However, looking more closely at the sentences, one encounters two types of sentences that are rather different in terms of their underlying semantic structure. This semantic structure is determined by the first verb of the sentences, which is a so-called control verb. Comrie (1985) showed that these verbs can be split-up into subject-control verbs and object-control verbs. Examples (8) to (10) from Steinhauer et al. contain a subject-control verb (*promise*), just as (17) and (18) (*confess*), which are example items used in the present thesis[1].

17. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben gespiekt ($V2_{intransitive}$)…
    The pupil (NP1) confessed (V1) (to) the teacher (NP2) to have cheated ($V2_{intransitive}$)…

18. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben opgesloten ($V2_{transitive}$)…
    The pupil (NP1) confessed (V1) to have locked up ($V2_{transitive}$) *the teacher (NP2)*…

V1 in these sentences (*confessed*) is a subject-control verb, because its subject (NP1; *the pupil*) is also the understood subject of the second verb in the sentence (V2; *cheat/lock up*); the pupil is the one that cheats and the one that locks someone up. However, the semantic structure changes if an object-control verb takes the V1 slot, as in examples (19) and (20) from the present thesis.

19. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te slapen ($V2_{intransitive}$)…
    The surgeon (NP1) advised (V1) the woman (NP2) to sleep ($V2_{intransitive}$)…

20. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te ondersteunen ($V2_{transitive}$)…
    The surgeon (NP1) advised (V1) [someone] to support ($V2_{transitive}$) *the woman (NP2)*…

In (19) and (20), V1 (*advised*) is a so-called object-control verb. In these sentences, the indirect object of V1 is the understood subject of the second verb in the sentence (V2). Thus, in (19) *the woman* is the understood subject of V2 (the woman should sleep). In (20) the indirect object of V1 is left implicit (this is acceptable in Dutch and indicated by *someone* in the translation), which means that the understood subject of V2 (the person supporting the woman) is also implicit, though it should be the same person as the one receiving the advice.

This difference in the underlying semantic structure of subject- and object-control sentences might very well lead to differences in parsing preference. We already know that verb biases (which could be different for subject- and object-control verbs) can affect the syntactic parsing of a sentence (see above, e.g., Itzhak et al., 2010). However, Steinhauer et al. (1999) collapsed the results over subject- and object-control (five subject-control verbs and seven object-control verbs). This might have obscured differences between these items. In Chapter 2 we analyze subject- and object-control sentences separately.

In the literature on the role of prosody in syntactic parsing, PBs are by far the most studied prosodic devices. However, other prosodic devices might also play a role in this process. Only some on-line studies looked at effects of other prosodic devices such as stress-

[1] Note that the content and form of the present sentences differs from Steinhauer et al. such that the sentences in our study contain full nouns rather than proper names. This is possible because in Dutch, in contrast to German, determiners and nouns do not carry case-marking. In this way, we could construct more varied sentence referring to more natural scenarios. These are probably easier to imagine and more interesting to listen to for participants.

patterns (Warren et al., 1995) and pitch accents (Schafer, Carter, Clifton, & Frazier, 1996) in the structuring of sentences. However, to our knowledge until now no studies have looked at the combined influence of PBs and other prosodic devices on sentence processing. In Chapter 3, we first replicate the ERP experiment of Chapter 2 with different filler items. Subsequently, we adapt this study to look at the role of pitch accents in the processing of these sentences. It is argued that pitch accents can provide focus not only to the accented word itself, but also to adjacent words, thereby grouping these words together. The effects of PBs and pitch accents will again be investigated for subject- and object-control sentences separately.

A point that concerns both Chapters 2 and 3 is the use of an additional task in ERP studies. As mentioned above, measuring ERPs in principle renders it unnecessary to have participants perform a task during the experiment, since the ERP itself provides the dependent measure. However, most studies described above nevertheless used an additional task, such as judging the appropriateness of the sentence prosody (e.g., Pauker et al., submitted) or answering comprehension questions about the items (e.g., Steinhauer et al., 1999). It is known that, for example, P600 effects can be influenced by task demands (see, e.g., Kolk, Chwilla, Van Herten, & Oor, 2003 for general task effects and Isel et al., 2005 and Astésano, Besson, & Alter, 2004 for task effects related to prosody). Probably, judging the appropriateness of the sentence prosody or answering explicit comprehension questions about syntactic relations strongly focuses listeners on the (relation between) prosody and syntax of the sentences. This, in turn, might lead to an unnatural enhancement of the effects or even lead to different effects. Therefore, in Chapters 2 and 3 we use a task that is as non-directive as possible, while still making sure that listeners attend to the sentences and try to understand them. Other aspects of the experiment can also affect listener's explicit focus on prosody, such as the presence of violations or mismatches in the stimuli and the presence of prosodic manipulations in the filler sentences. This latter aspect is addressed in Chapter 3 as well.

1.2 Pitch accents in referential communication

Now we turn to another domain of language processing in which pitch accents play a role. In a conversation, speakers often want to direct listeners' attention to a certain object, a situation that is usually called referential communication. Intuitively, it is plausible that listeners can identify the correct object more easily when its contrastive aspects relative to other possible objects are emphasized or put in focus. For example, imagine someone wants to refer to his car in contrast to other cars nearby. If the color of his car is contrastive, that is, different from the colors of the other cars, it might help listeners when he emphasizes the color by accenting it: *The RED car is mine*.

We distinguish two different types of contrast. The first is a contrast with other objects that are visually present (visual context), as in the above example. In this case, it seems important for listeners to attend to this contrast, since this is the property that allows the listener to uniquely identify the intended referent. The second is a contrast with objects that were previously mentioned in the discourse (linguistic context; e.g., *You have a yellow car, but I have a RED car*). Here, it might be important for listeners to attend to the contrastive property (*red*) since it is the new aspect in the discourse, whereas the other information (*car*) was already mentioned in the discourse and is thus already known.

These are some plausible considerations about the potential usefulness of pitch accents to indicate contrasts for listeners. However, these are only intuitions. Though intuitions are an important first step in the investigation of referential communication, observation and/or experimentation have to follow it to gather reliable knowledge (Clark & Bangerter, 2004). Experimentation in the lab can lead to a more-or-less unnatural situation, which sometimes makes it hard to determine in how far the conclusions generalize to real life language processing. However, experimentation allows for the systematic control and manipulation of potentially relevant factors. Therefore, in Chapter 4 we use carefully controlled experimentation in a simplified situation as a first step to investigate the role of accentuation in referential communication. More specifically, we investigate how listeners process pitch accents that mark contrasts in the visual and linguistic context. Before we give a preview of Chapter 4, we briefly review relevant comprehension and production studies on this issue.

1.2.1 Comprehension of pitch accents in referential communication

Processing of pitch accents in referential communication was first investigated using reaction time methods and visual methods, such as eye-tracking. Sometimes, the two types of contrast described above were confounded. For example, Weber, Braun, and Crocker (2006) used visual displays with four objects, e.g., a green clock, a red vase, purple scissors, and red scissors. In such a display a visual contrast exists between the colors of the two pairs of scissors. Participants listened to utterances like (21) and (22) while watching the display.

21. Click on the purple scissors. Now click on the RED scissors.
22. Click on the purple scissors. Now click on the red SCISSORS.

When the adjective was accented as in (21), listeners looked at the correct object (red scissors) earlier than when the noun was accented as in (22). However, in this case, there is both a contrast with respect to the linguistic context, since the purple scissors were mentioned in the previous sentence AND a contrast in the simultaneous visual context, since the two pairs of scissors form a contrast in the visual display. Therefore, it is not clear which of the two contrasts (or both) caused the effect.

Other studies looked at only one type of contrast, but most of these studies focused on the linguistic context.

Linguistic context. Early studies looked at how fast accented and unaccented words are recognized. In general, new words in the discourse were recognized faster when they were accented and given words were recognized faster when they were unaccented (e.g., Terken & Nooteboom, 1987), especially for speech that was reduced in quality by using noise (Van Donselaar & Lentz, 1994).

Using eye-tracking, Ito and Speer (2008) investigated whether accentuation of new information helped listeners to identify the correct object during a visual search task. Participants received instructions to decorate a Christmas tree with objects from a large array of objects in different colors. When an instruction about a colored object (e.g., a blue angel) was followed by an instruction about the same object with a different color (e.g., a red angel), the correct item was fixated earlier when the adjective was accented (e.g., *take a RED angel*) than when it was deaccented (e.g., *take a red ANGEL*).

In an eye-tracking study by Dahan, Tanenhaus, and Chambers (2002), participants saw displays that contained two objects with a similar onset sound (e.g., candle and candy). They received instructions such as (23) and (24).

23. Move the candy above the triangle. Now put the CANDY below the square.
24. Move the candle above the triangle. Now put the CANDY below the square.

When the noun in the second sentence was accented, listeners in first instance looked more often to the object that was not mentioned in the first sentence.

These eye-tracking studies show that listeners interpret accented words as new information and deaccented words as given information. A few ERP studies have investigated contrastive information in the linguistic context. For example, Magne, Astésano, Lacheret-Dujour, Morel, Alter, and Besson (2005) used question-answer pairs such as (25a) and (25b).

25. Did he give a ring or a bracelet to his wife?
    a. He gave a RING to his wife.
    b. He gave a ring to his WIFE.

The answer in (a) has the expected intonation pattern since *ring* is contrasted with bracelet in the previous sentence, whereas *wife* is old information. By using ERPs, it is possible to look at different positions in the sentence. This is interesting because (25b) contains two mismatches in terms of accentuation. First, *wife* is accented while it provides given information, thus the accent is superfluous. Second, *ring* is deaccented while it provides contrastive information, thus an accent is missing here. Magne et al. found evidence in the ERPs for processing difficulties at both positions. However, other studies only found evidence for processing difficulties at missing accents, but not at superfluous accents (Hruska & Alter, 2004; Hruska, Alter, Steinhauer, & Steube, 2001; Johnson, Clifton, Breen, & Morris, 2003; Toepel et al., 2007).

Visual context. We know of only one study that looked at processing of pitch accents in the visual context (Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995). Participants were presented with displays of four objects (large blue square, small blue square, large yellow circle, small red triangle). Listeners were instructed to touch one of the objects as in (26).

26. Touch the LARGE blue square.

When hearing the accented word *large*, listeners immediately looked more frequently to large targets with a small competitor (large blue square) than large targets without such a competitor (large yellow circle), but this was only the case when only one size contrast was present in the display. This result shows that listeners can interpret pitch accents as an indication of a contrast in the visual context.

1.2.2 Production of pitch accents in referential communication

Although the main topic of this thesis is the processing of prosody in language comprehension, a related question is whether speakers actually produce these accents to indicate contrasts in the linguistic and/or visual context. One would expect speakers to use pitch accents to indicate these contrasts since they are probably useful for listeners. However, these considerations are again based on intuition, and experimentation is needed to investigate the exact relation between perception and production of pitch accents.

Dutch referential utterances in a linguistic context have been investigated using a communication game between two participants (Krahmer & Swerts, 2001; Swerts, Krahmer, & Avesani, 2002). In this game, participants took turns in describing geometrical objects to each other, using the color and the shape of the objects (e.g., *red triangle*). With respect to the previous utterance (from the other speaker), the current color, shape, or both aspects could be new. It was found that Dutch speakers generally accented the aspect that was new, and deaccented the aspect that was given in the previous utterance. However, a different pattern arose for the condition where both aspects were new. Some participants accented both aspects (e.g., RED TRIANGLE) and some accented only the noun (e.g., red TRIANGLE). However, in the latter case the accent on the noun had a smaller pitch excursion than for the condition where the object was the only new aspect. Thus, it seems that speakers produce at least three different kinds of accentuation patterns for simple referential utterances like *red triangle*.

To our knowledge, only one study (Pechmann, 1984) looked at the production of (Dutch) referential utterances in both the linguistic and the visual context. Although not instructed to do so, the large majority of speakers in his experiment overspecified their utterances when referring to objects in a display. That is, they specified both the color and the object of the referent, also in cases where mentioning only the object or only the color would have sufficed to identify the object. Pechmann used only two categories to code the speakers' utterances: accent on the noun and accent on the adjective. By default, speakers accented the noun (e.g., *the red BALL*). However, in a condition where the speakers themselves had just before referred to the same object with a different color (i.e., they had just said *the blue BALL*), the color was accented in 90 to 100% of the cases (*the RED ball*). Clearly, speakers marked a contrast in the linguistic context with a pitch accent.

In the critical visual context condition, speakers referred to an object with the same shape but a different color than a context object in the same visual display (e.g., a picture of a red and a blue ball). In this case, speakers produced the default pitch accent on the noun (*the red BALL*). This study thus suggests that speakers consistently mark contrasts in the linguistic context with pitch accents, while they do not mark contrasts in the visual context.

The latter result seems surprising, but one has to keep in mind that it is not known whether this result would generalize to more natural language situations outside the laboratory. In section 4.6 of Chapter 4, a small production study will be reported which addresses an alternative explanation for the result in the visual context condition. The apparent discrepancy in the production of pitch accents in the linguistic versus the visual context found by Pechmann (1984) leads one to wonder whether a similar discrepancy exists in the comprehension of pitch accents.

1.2.3 Preview of Chapter 4

The ERP study reported in Chapter 4 investigates the processing of pitch accents in visual and linguistic contexts. By combining both types of context in the same experiment and the same kind of referential communication situation, we can see whether linguistic and visual contexts lead to comparable effects. To keep the materials as simple as possible, displays with two objects are used, followed by a simple spoken reference to one of these.

27. [blue ball red bike]
    the blue ball

    [green ball blue car]
    a. *the GREEN ball*
    b. *the green BALL*
    c. *the green ball* (neutral accentuation)

In (27), an example is given of a linguistic context item[2] (consisting of two successive displays and utterances), in which the sequences in square brackets stand for a display with two colored objects. The utterance in (a) has a matching accentuation relative to the previous utterance. The accentuation in (b) mismatches with the previous utterance in that an accent on *green* is missing and *ball* has a superfluous accent. We also added a condition with a so-called 'neutral' accentuation, containing an 'intermediate' accent on both the adjective and the noun. For this neutral accentuation, we used the type of accent that would fit a context where both aspects (color and object) are different from the previous utterance (see Krahmer & Swerts, 2001).

28. [blue ball red ball]
    a. the BLUE ball
    b. the blue BALL
    c. the blue ball (neutral accentuation)

In (28) the contrast is present in the visual context, since the other object which is simultaneously present in the display (red ball) has a different color from the target object. Again, the accentuation in (a) matches the contrast in the visual context, the accentuation in (b) has a missing accent on *blue* and a superfluous accent on *ball*, and the accentuation in (c) is intermediate.

1.3 Compilation of the thesis

All chapters of this thesis are completely or partly published or submitted for publication. Parts of Chapters 1 and 5 are based on a submitted article. Chapters 2 to 4 are presented as they are published or submitted, with the exception of the numbering of the sections, references to other chapters and some of the sections following the (General) Discussion. At

[2] Note that the context is not purely linguistic, since visual displays are present. Strictly speaking, the contrast is present both with respect to the preceding linguistic utterance AND with respect to the preceding visual display. However, we will refer to these types of items as the *linguistic context*, to contrast them with items in which the contrasting objects are visually present *simultaneously* with the target object.

each of these sections it is stated in a footnote whether the section was published as an Appendix to the article. The materials from Chapters 2 and 3 are presented in Appendix I at the end of this thesis, while they were originally provided in Appendix A of the two articles. Inevitably, some overlap exists between the introductions of the chapters. The references from all chapters are assembled in a separate section at the end of the thesis. Tables, figures, and footnotes are numbered consecutively within each chapter.

Chapter 2

The interplay between prosody and syntax in sentence processing: The case of subject- and object-control verbs

Abstract

This study addresses the question whether prosodic information can affect the choice for a syntactic analysis in auditory sentence processing. We manipulated the prosody (in the form of a prosodic break (PB)) of locally ambiguous Dutch sentences to favor one of two interpretations. The experimental items contained two different types of so-called control verbs (subject- and object-control) in the matrix clause and were syntactically disambiguated by a transitive or intransitive verb. In Experiment 1 we established the default off-line preference of the items for a transitive or an intransitive disambiguating verb with a visual and auditory fragment completion test. The results suggested that subject- and object-control verbs differently affect the syntactic structure that listeners expect. In Experiment 2 we investigated these two types of verbs separately in an on-line ERP study. Consistent with the literature, the PB elicited a Closure Positive Shift (CPS). Furthermore, in subject-control items, an N400 effect for intransitive relative to transitive disambiguating verbs was found, both for sentences with and for sentences without a PB. This result suggests that the default preference for subject-control verbs goes in the same direction as the effect of the PB. In object-control items, an N400 effect for intransitive relative to transitive disambiguating verbs was found for sentences with a PB, but no effect in the absence of a PB. This indicates that a PB can affect the syntactic analysis that listeners pursue.

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When processing a sentence, several sources of information (e.g., syntactic, semantic, and discourse information) are available to arrive at the correct interpretation of the sentence. The majority of research on sentence processing has focused on reading. However, auditory sentence processing is probably more frequent in everyday life. Furthermore, spoken sentences also contain (explicit) prosodic information as an additional potential source that can help sentence interpretation. Prosody can be defined as "those phenomena that involve the acoustic parameters of pitch, duration and intensity" (Ladd & Cutler, 1983, p. 1). The present study addresses the question whether prosody can affect the choice for a syntactic parse in locally ambiguous sentences.

Off-line methods, such as questions after hearing a globally ambiguous sentence, have revealed that the place of prosodic boundaries and pitch accents can determine the interpretation of a sentence (e.g., Streeter, 1978; Schafer, 1995; Schafer et al., 1996). Prosody can also help to choose between two possible endings for a locally ambiguous sentence (Beach, 1991; Stirling & Wales, 1996). Other studies used cross-modal naming, an on-line method. Most of these studies (Marslen-Wilson et al., 1992; Warren et al., 1995; Kjelgaard & Speer, 1999; but see Rösler, Friederici, Pütz, & Hahne, 1993) found that prosody can affect on-line parsing preferences. However, with this method sentences are presented partially and participants have to perform a rather unnatural task. Event-Related Potentials (ERPs) can counter these problems and, moreover, provide a measure of processing across the whole sentence.

The present study builds on an ERP study by Steinhauer et al. (1999) on the processing of auditorily presented German sentences as in (1) and (2).

1. Peter verspricht Anna zu arbeiten… (*Peter promises Anna to work…*)
2. Peter verspricht Anna zu entlasten… (*Peter promises to support Anna…*)

Note that in German (in contrast to English) (1) and (2) are exactly the same up to the second verb and are syntactically disambiguated by this verb. In (1) *Anna* is the indirect object of the verb *verspricht*. This becomes clear at the verb *arbeiten*, because this is an intransitive verb. In (2), by contrast, *Anna* must be the direct object of the verb *entlasten*, because this is an obligatorily transitive verb. According to Steinhauer et al. (1999), without other cues, (2) will lead to a garden path effect because *Anna* is initially regarded as the indirect object of *verspricht*. This initial preference is thought to be driven by the minimal attachment principle (Frazier, 1987; see Steinhauer, 2003, p. 145). Steinhauer et al. (1999) also propose that a prosodic break after *verspricht* can provide an earlier disambiguation, before the second verb, that should reverse this garden path effect and lead to processing difficulty at the intransitive verb *arbeiten* in (1) relative to the transitive verb *entlasten* in (2).

A prosodic break (PB) or boundary consists of a pause, prefinal lengthening of the last stressed syllable before the pause and a boundary tone (see, e.g., Kjelgaard & Speer, 1999). A PB after *verspricht* provides a break between *verspricht* and *Anna*, which is likely to prevent *Anna* from being considered as the indirect object of *verspricht*. If this is the case, the PB disambiguates the sentence towards the structure in (2) and the intransitive verb *arbeiten* (as in (1)) causes a garden path effect.

In line with this reasoning, Steinhauer et al. (1999) found a biphasic N400-P600 effect in response to the disambiguating intransitive verb *arbeiten* relative to the transitive verb *entlasten* when a PB was present after *verspricht*. The N400 effect was regarded as a reflection of lexical re-access to confirm the violation of the intransitive argument structure, the P600 effect as a structural revision. These results were taken to show a prosody-induced garden path effect. Moreover, the Closure Positive Shift (CPS; Steinhauer et al., 1999) was discovered at the position of the PB for sentences with a PB, whereas this ERP component was absent at the equivalent position in sentences without a PB.

The present study uses similar materials as Steinhauer et al. (1999) in Dutch; see (3) and (4).

3. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben gespiekt ($V2_{intransitive}$)...
   The pupil (NP1) confessed (V1) (to) the teacher (NP2) to have cheated ($V2_{intransitive}$)...

4. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben opgesloten ($V2_{transitive}$)...
   The pupil (NP1) confessed (V1) to have locked up ($V2_{transitive}$) the teacher (NP2)...

The first verb (V1; *bekende*, 'confessed' in (3) and (4) and *verspricht*, 'promises' in (1) and (2)) is a so called control verb. In the linguistic literature, subject-control (SC) verbs and object-control (OC) verbs are distinguished (e.g., Comrie, 1985). The verb *bekende* ('confessed') in (3) and (4) is an SC verb, because the subject of this verb (*de leerling,* 'the pupil') takes on the function of subject of the following infinitive complement (*hebben gespiekt*, 'have cheated' in (3) or *hebben opgesloten,* 'have locked up' in (4)). The verb *adviseerde* ('advised') in (5) and (6) is an OC verb, because its (explicit or implicit) indirect object takes on the function of subject of the following infinitive complement (*slapen*, 'sleep' in (5) and *ondersteunen,* 'support' in (6)).

5. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te slapen ($V2_{intransitive}$)...
   The surgeon (NP1) advised (V1) the woman (NP2) to sleep ($V2_{intransitive}$)...

6. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te ondersteunen ($V2_{transitive}$)...
   The surgeon (NP1) advised (V1) to support ($V2_{transitive}$) the woman (NP2)...

If the sentence contains an intransitive V2 such as (5), NP2 (*de vrouw,* 'the woman') is the explicit object of V1 and the understood subject of V2 (*slapen*, 'sleep'). In case of a transitive V2, as in (6), the object of V1 is not mentioned. This implicit object is the understood subject of V2 (*ondersteunen*, 'support'). In the following, items containing a subject-control V1 are called SC items and items containing an object-control V1 are called OC items. In the materials of Steinhauer et al. (1999), five SC and seven OC verbs were used (personal communication). In contrast to Steinhauer et al. (1999) who did not differentiate between SC and OC verbs, and thus implicitly assumed that the two verb types are processed in the same way, in the present study we investigate whether differences in processing exist between SC and OC items.

We presented participants with sentences like (3) to (6) both with and without a PB after V1. This yields a design in which the two factors *prosodic break* (present or absent) and *disambiguating verb* (transitive or intransitive) are fully crossed. This design differs from the one used by Steinhauer et al. (1999), who presented the German equivalents of (3) and (5) with and without a PB, but the equivalents of (4) and (6) only with a PB.

In the present ERP study (Experiment 2 below), we expect to find a CPS in response to the PB (e.g., Steinhauer et al., 1999; Steinhauer & Friederici, 2001; Isel et al., 2005; Pannekamp et al., 2005; Kerkhofs et al., 2007; 2008).

The results at the disambiguating verb (V2) should depend on the default analysis that listeners pursue. As already indicated, Steinhauer et al. (1999) assume that NP2 will by default be interpreted as the indirect object of V1 and an intransitive disambiguating verb should fit this preference. However, they could not test whether this assumed default preference really holds, because in their design, sentences with a transitive V2 were never presented without a PB. This implies that the relevant comparison to establish the default preference, no PB transitive versus no PB intransitive, was not included in their design. With a fully crossed design, we can test this assumed default preference.

Moreover, given potential differences between the two types of control verbs, it is not certain whether a preferred default analysis will be the same for SC and OC items. To our knowledge no earlier studies explicitly contrasted the processing of SC and OC verbs. In Experiment 1, we first establish the off-line default preference for an intransitive versus a transitive disambiguating verb in SC and OC items in a visual and auditory fragment completion test (FCT). The auditory FCT additionally provides us with the possibility to look at the potential off-line effects of the absence or presence of a PB after V1.

2.1 Experiment 1

2.1.1 Methods

Participants. Participants were 30 native speakers of Dutch (four males), with no reading problems and a mean age of 20.2, for the visual FCT and 20 other native speakers of Dutch (one male) with a mean age of 21, with no reading and/or hearing problems, for the auditory FCT. The participants were paid or received course credit for their participation.

Materials. As a starting point, we searched for all Dutch control verbs suitable for our experimental sentences. We found 14 SC verbs and 10 OC verbs. Because of the relatively small number of available control verbs in Dutch, we created two different items for each control verb. An example of an SC and an OC item can be found in Table 2.1. All sentences were of the form [NP1][V1][NP2][V2], followed by at least four words. V1 was always a control verb. In one version of each item, V2 was intransitive and in the other version it was obligatorily transitive. In some of the SC items an auxiliary was placed between NP2 and V2 in order to make the sentences sound more natural. See the Appendix I at the end of this thesis for the resulting 28 SC and 20 OC items.

For the auditory FCT, these items were recorded by a female native speaker of Dutch, in two versions: with a transitive and an intransitive V2. She first read each sentence silently for herself and then out loud. Each sentence was recorded three times. Sentences with a transitive V2 were produced with a PB after V1 (see sentences C1 and C2 in Table 2.1), and sentences with an intransitive V2 were produced without such a PB (see sentences B1 and B2 in Table

2.1). All sentences were produced with a PB after V2. For every item, the best token of each version was chosen by the experimenters on the basis of intuition. This token was cut in two parts in the silence before the [t] of *te* ('to') preceding V2. Only the first part was used. This resulted in two different tokens of the form [NP1][V1][NP2] per item, one with and one without a PB after V1.

Table 2.1 Examples of the experimental sentences. Intonational phrases, separated by PBs, are indicated by square brackets. For the visual FCT the sentences were presented until [2] and for the auditory FCT they were presented auditorily until [1] and visually from [1] to [2]. English translations are given in italics.

		Subject-control (SC)
A1	PB, intransitive V2	[De leerling bekende] [de leraar[1] te hebben[2] gespiekt] [tijdens het eerste uur.] *[The pupil confessed] [(to) the teacher to have cheated] [during the first hour.]*
B1	No PB, intransitive V2	[De leerling bekende de leraar[1] te hebben[2] gespiekt] [tijdens het eerste uur.] *[The pupil confessed (to) the teacher to have cheated] [during the first hour.]*
C1	PB, transitive V2	[De leerling bekende] [de leraar[1] te hebben[2] opgesloten] [tijdens het eerste uur.] *[The pupil confessed] [to have locked up the teacher] [during the first hour.]*
D1	No PB, transitive V2	[De leerling bekende de leraar[1] te hebben[2] opgesloten] [tijdens het eerste uur.] *[The pupil confessed to have locked up the teacher] [during the first hour.]*
		Object-control (OC)
A2	PB, intransitive V2	[De chirurg adviseerde] [de vrouw[1] te[2] slapen] [voor de zware operatie.] *[The surgeon advised] [the woman to sleep] [before the heavy surgery.]*
B2	No PB, intransitive V2	[De chirurg adviseerde de vrouw[1] te[2] slapen] [voor de zware operatie.] *[The surgeon advised the woman to sleep] [before the heavy surgery.]*
C2	PB, transitive V2	[De chirurg adviseerde] [de vrouw[1] te[2] ondersteunen] [voor de zware operatie.] *[The surgeon advised] [to support the woman] [before the heavy surgery.]*
D2	No PB, transitive V2	[De chirurg adviseerde de vrouw[1] te[2] ondersteunen] [voor de zware operatie.] *[The surgeon advised to support the woman] [before the heavy surgery.]*

We performed acoustic analyses on these sentence parts (see Table 2.2 for means and SDs) in the form of ANOVAs with PB (PB, no PB) as within-item factor and Control (subject-control, object-control) as between-item factor. Analyses on the length and pitch range of NP1 and the length of the unstressed syllable(s) of V1 preceding the stressed syllable, revealed no effects of PB (ps > .06), nor interactions between PB and Control (Fs < 1). However, prefinal lengthening took place in the last stressed syllable of V1 and following unstressed syllables; these syllables were longer in the PB condition than in the no PB condition ($F(1,42) = 1142.26$, $p < .001$)[1]. The prefinal lengthening was more pronounced in the SC items (197 msec) than in the OC items (169 msec), which is reflected in an interaction between PB and Control ($F(1,42) = 6.91$, $p < .05$). Moreover, the pitch track was qualitatively different for the PB and no PB sentences. In sentences with a PB, a boundary tone occurred on the last syllable before the pause whereas in sentences without a PB no boundary tone was present and pitch accents occurred on V1. This was the case for both SC and OC items. Furthermore, in the sentences with a PB, a pause was present between V1 and NP2, which did not differ in length between the SC and OC items ($p > .20$). No pause at this position was present in sentences without a PB. In summary, examination of the three features of the PB

[1] In two instances, namely the verbs *antwoorden* (to answer) and *waarschuwen* (to warn), the main stress is on the first syllable, but the second syllable is stressed as well. We decided to exclude these items from the acoustic analyses of V1.

indicated that the first acoustic information about the PB becomes available not earlier than the last stressed syllable before the pause, for both SC and OC items.

Table 2.2 Means and SDs for the acoustic analyses, separately for the subject- and object-control items.

	Subject-control items		**Object-control items**	
	M_{PB} (SD)	$M_{no\ PB}$ (SD)	M_{PB} (SD)	$M_{no\ PB}$ (SD)
NP1 length (msec)	464 (106)	468 (104)	524 (133)	532 (133)
NP1 pitch range (Hz)	54 (18)	55 (19)	48 (13)	45 (10)
V1 unstressed length* (msec)	117 (78)	113 (66)	129 (59)	122 (59)
V1 stressed length** (msec)	498 (76)	301 (72)	442 (75)	273 (63)
Pause length	308 (85)	-	327 (70)	-

* V1 unstressed length = length of unstressed syllable(s) of V1 preceding the stressed syllable
** V1 stressed length = length of the stressed syllable and following unstressed syllable(s) of V1

As filler sentences for both FCTs, 60 simple sentences were taken from Hagoort and Brown (1994). These sentences had two versions, with a high or with a low cloze noun (e.g., *Jenny put the sweet in her [mouth*$_{\text{high cloze}}$*/pocket*$_{\text{low cloze}}$*] after the lesson.*). For the auditory FCT, these sentences were recorded by another female native speaker of Dutch.

Design. We looked at the preference for intransitive or transitive completions, for SC and OC items. For the auditory FCT, we additionally included the factor PB. The items were presented in a pseudo-random order such that no more than three experimental items were presented in a row. Two lists were created by switching the halves of the experiment. Furthermore, in the auditory FCT, every experimental item occurred once in one half of a list (with or without a PB) and once in the other half of the list, but in the other condition (without or with a PB).

Procedure. In the visual FCT, the experimental items were presented up to but not including the disambiguating V2 (up to position [2] in Table 2.1). The filler items were presented up to but not including the high or low cloze word. The items were presented in a booklet and participants had to write down their completions after each item. They were instructed to complete each sentence fragment in two correct and plausible ways. The first seven and the last five items in the booklet were filler items.

In the auditory FCT, participants had to complete the sentence fragments in one correct and plausible way. A warning beep preceded every item. The experimental items were presented auditorily via headphones up to and including NP2 (position [1] in Table 2.1). The word *te* (‘to’), was not presented auditorily because co-articulation in the schwa of *te* would reveal information about the next phoneme. Following the auditory fragment, *te* or *te* plus auxiliary (position [1] till [2] in Table 2.1) were presented visually on a computer screen, followed by a blank field in which participants typed their completion of the sentence. The filler fragments were presented auditorily up to one or two words before the high or low cloze noun (e.g., *Jenny put the sweet* for the example given above) and the remaining words (*in her*) were presented visually. The experiment started with a practice block and consisted of three blocks. Each block was preceded by three starter sentences and followed by a short pause.

2.1.2 Results

For the visual FCT, the first response was scored as either a transitive or an intransitive verb. When the verb provided in the first response could not be interpreted as exclusively transitive or intransitive in this context, we scored the second response. If this response was ambiguous as well, the corresponding participant's and item's score was treated as a missing value (1.25% out of 1440 responses). OC items clearly received more intransitive completions than SC items ($t(46) = -9.13$, $p < .001$). SC items received 41% intransitive completions, which was not significantly different from 50% ($t(27) = -1.79$, $p > .08$), whereas OC items showed an overwhelming intransitive preference (97%) differing from 50% ($t(19) = 40.17$, $p < .001$). In Figure 2.1, panel A, the distributions of intransitive completions for SC and OC items are presented, showing that they differ clearly and are in fact almost non-overlapping.

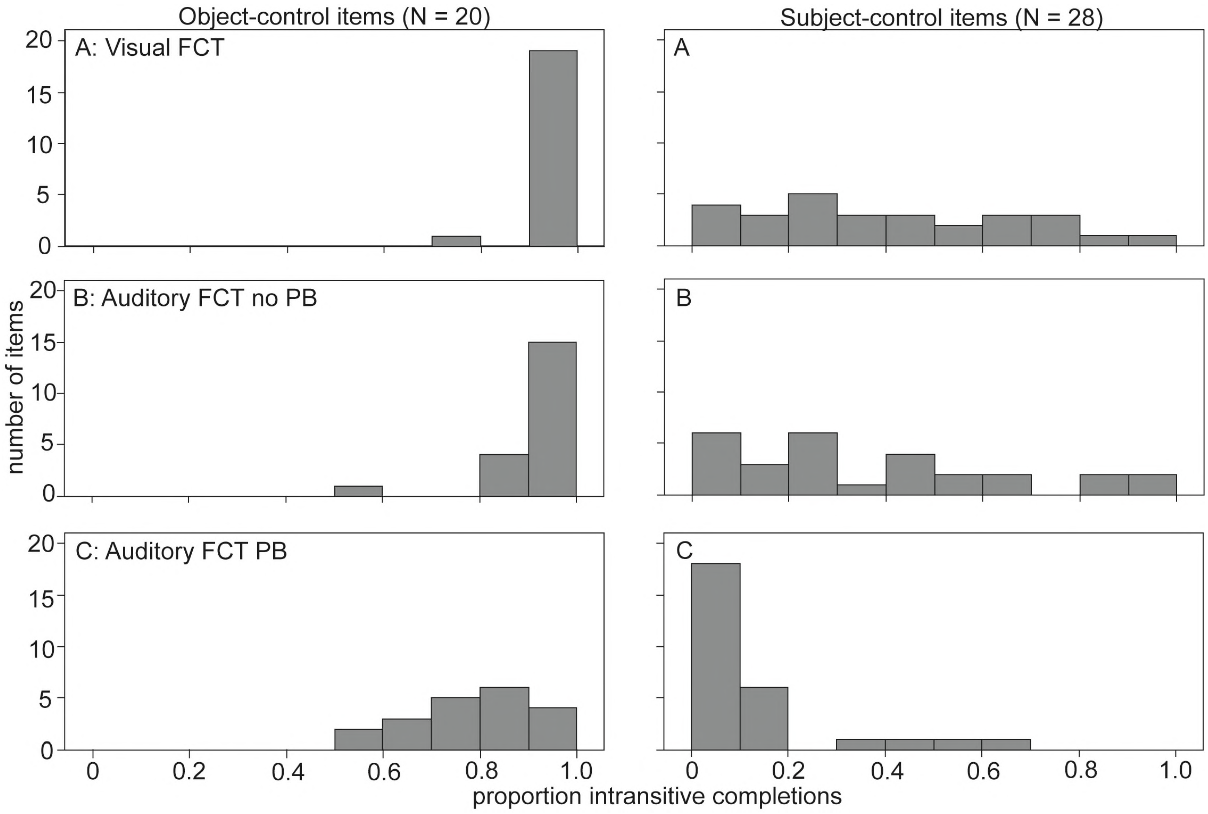

Figure 2.1 Distributions of items over the proportion of intransitive completions in the FCTs (x-axis). The y-axis represents the average number of items that fall in the respective proportion ranges. OC items (N = 20) are presented on the left, SC items (N = 28) on the right. Panel A displays the distribution of the visual FCT, panels B and C display the auditory FCT, in the no PB and the PB condition, respectively.

Each completion in the auditory FCT was scored as transitive, intransitive, or ambiguous. The last category was discarded (11.0% out of 960 responses). An ANOVA was performed on the percentage of intransitive completions, with PB (PB, no PB) as within-item factor and Control (subject-control, object-control) as between-item factor. OC items received more intransitive completions (PB: 91%; no PB: 78%) than SC items (PB: 10%, no PB: 36%; $F(1,46) = 132.64$, $p < .001$). More intransitive completions were given in the PB than in the no PB conditions ($F(1,46) = 61.06$, $p < .001$) and this effect of PB was somewhat larger for

SC than OC items ($F(1,46) = 6.74$, $p < .05$). All preferences differed from 50% (ps < .05). Panels B and C in Figure 2.1 display the distributions of intransitive completions for SC and OC items for the no PB and PB conditions.

2.1.3 Discussion

The FCTs indicate a very strong preference for intransitive completions in OC items, whereas SC items show a slight preference for transitive completions. Comparing the two FCTs, the results for the visual FCT are very similar to the results for the no PB condition of the auditory FCT (see panels A and B in Figure 2.1). Extrapolating these results to on-line processing, the FCTs suggest that for OC verbs that are not followed by a PB, a transitive V2 should lead to processing difficulty relative to an intransitive V2. In terms of Steinhauer et al. (1999) this would reflect a garden-path effect when the minimal attachment preference for an intransitive V2 is not confirmed at V2. By contrast, if a PB is present after the control verb (V1), the data by Steinhauer et al. (1999) would lead one to expect a reversed garden-path effect, showing processing difficulty for an intransitive V2 relative to a transitive V2. Two points should be noted in this context, however. First, the former prediction concerning a garden path effect in the case of no PB could not be tested in the study of Steinhauer et al. (1999) due to the fact that they did not use a fully crossed design. Second, the auditory FCT-data show that a PB after an object-control V1 can reduce the preference for intransitive completions (to 78%), but it clearly does not eliminate it, or even reverse it to a transitive preference.

For SC verbs, the auditory FCT shows a very different pattern, namely a preference for a transitive V2, present both in the no PB and in the PB condition. In terms of on-line processing, an SC verb not followed by a PB should lead to processing difficulty for an intransitive relative to a transitive V2. The effect of a PB after V1 should go in the same direction. Therefore, it is questionable whether on-line data will show a strengthening of this effect by the PB. In Experiment 2, these predictions are tested using ERPs.

2.2 Experiment 2

2.2.1 Methods

Participants. Participants were 36 right-handed native speakers of Dutch, with no hearing problems. They were paid or received course credit for their participation. Excessive artifacts led to exclusion of 8 participants. The remaining 28 participants (five male) had a mean age of 21.7 years.

Materials. The materials for the ERP experiment were constructed from the recorded sentences for Experiment 1 (see Table 2.1, sentences B and C for example sentences). Of these sentences we chose two tokens without a PB and with an intransitive V2 (sentences B1 and B2 in Table 2.1) and two tokens with a PB and a transitive V2 (sentences C1 and C2 in Table 2.1). After cutting these four chosen tokens in two parts before *te* ('to') preceding V2 (position[1] in Table 2.1), only the first or the last part of each token was used. This resulted in two 'first parts' of tokens (with and without PB; already used in the auditory FCT) and two 'second parts' of tokens (with a transitive and with an intransitive V2). With these four parts, four new experimental tokens were created by cross-splicing: two tokens with a transitive V2 and two tokens with an intransitive V2, both with and without PB.

Next to these experimental sentences, 120 filler sentences were created, recorded and cross-spliced. These consisted of locally ambiguous NP- and S-coordination sentences (see Kerkhofs et al., 2007). Also 32 additional sentences were created, recorded and cross-spliced, half of a similar type as the experimental items, and half of the type of the filler items. Of these, 20 were used as a practice block before the experiment and 12 as starter sentences, two per block of the experiment (see Procedure).

Design. The design contains three factors: PB (PB, no PB), Structure (transitive V2, intransitive V2), and Control (subject-control, object-control), which is between-item. Two separate sub-designs are present, one for the OC items and one for the SC items, each with the fully crossed factors PB and Structure. Four lists of experimental sentences were created. Each experimental item occurred in all four conditions in each list. This implies that every participant heard the same item four times. However, the (critical) disambiguating verb was only repeated twice for each item, once in a sentence with a PB and once in a sentence without a PB. Furthermore, we constructed the lists such that every item occurred only once in each quarter of a list. Counterbalancing ensured that across lists each item occurred in all four conditions across the four quarters. The conditions were counterbalanced within each list and each quarter such that every condition had the same mean rank over items. This ensured an even distribution of the different conditions of both the SC and the OC items over the experiment and over the four quarters.

The 112 (28 * 4) experimental SC sentences and 80 (20 * 4) experimental OC sentences in each list were combined with the 120 filler sentences to a total of 312 sentences. For each list, a pseudo-random order of the experimental and filler sentences was determined with the restriction that no more than three experimental items or two filler items were presented in a row.

Procedure. The participants were tested in a soundproof and dimly lit room and heard the sentences over headphones. A written and oral instruction informed them about the course of the experiment. They were instructed to listen carefully and to try to imagine what the sentences were about. A trial started with a warning beep of 100 milliseconds. The sentence started 500 milliseconds after onset of the warning beep. Participants were asked to look at a fixation cross and to avoid eye blinks and eye movements from the warning beep until the offset of the sentence. They were allowed to make eye movements in a period of 4 seconds between the offset of a sentence and the next warning beep. In this interval, normal background noise (recorded in between the sentences during the recording) was presented, because a period of complete silence between the sentences sounds unnatural.

First, participants were trained to fixate on the screen without making any eye-movements, in a practice block of 20 sentences. Then six experimental blocks were presented, each consisting of two starter sentences and 52 experimental and filler sentences. Immediately after an experimental block, participants had to decide which of two written sentences on a piece of paper they had heard in the previous block and which not. Both sentences had the same structure as the items in the experiment, but only one had actually occurred in the previous block. This task was not very demanding and was administered to ensure that the participants paid attention while listening to the sentences.

Apparatus. The EEG was recorded from 25 tin electrodes. Electrode positions were a subset of the international 10-20 system. Three midline electrodes (Fz, Cz, and Pz) and 22 lateral electrodes (AF7/8, FT7/8, F7/8, F3/4, FC3/4, T7/8, C3/4, CP5/6, P7/8, P3/4, and PO7/8) were used, as in earlier auditory ERP studies (e.g., Kerkhofs et al., 2007). The left-mastoid was used as a reference during the recording, but the signal was re-referenced to software linked mastoids before the analysis. Eye blinks were monitored by vertical EOG electrodes above and below the right eye and horizontal eye movements by two electrodes at the outer canthi. Electrode impedance was kept below 5 kΩ for EOG- and below 3 kΩ for EEG-electrodes. Signals were amplified with a time constant of 8 seconds and a bandpass filter of .05 to 100 Hz and digitized with a 16-bit A/D converter at a sampling frequency of 500 Hz.

2.2.2 Results

Performance on test questions. Of the 28 participants, 26 participants identified the right sentence in all six cases and the remaining two participants made only one error.

Data-analysis for ERP data. The EEG data were filtered with a 30 Hz lowpass filter and afterwards time-locked to the critical positions in the sentence. In previous studies, ERPs have been time-locked to different positions in the sentence to measure the effect of a PB. Steinhauer et al. (1999) time-locked to sentence onset and determined CPS onset relative to the average position of the pause in the sentence. A disadvantage of this method is considerable latency variability across items in the onset of the pause. This problem is avoided by Kerkhofs et al. (2007), by time-locking to the onset of the pause in the conditions with a PB; the offset of V1 in the present experiment. This time-locking point has the disadvantage that information about other features of the PB (preceding the pause), such as prefinal lengthening and boundary tone, are already available before pause onset. These features are presumably important in eliciting the CPS, since a PB from which the pause is removed, can still elicit a CPS (Steinhauer et al., 1999). Therefore, we chose an intermediate time-locking point in the sentence, located just before prefinal lengthening and boundary tone started. On the basis of the acoustic analyses reported in the Materials section of Experiment 1, we identified this position as the onset of the last stressed syllable before the pause[2]. This point leads to less latency variability in onset of the pause across items than sentence onset, while the acoustic markers of the PB that precede the pause are taken into account. We computed averages for 2000 msec after onset of this point. To compare it to the points used in previous research, we also analyzed the results using the two time-locking points used in earlier studies (sentence onset and pause onset). Section 2.6 reports on these analyses and shows grand average waveforms for these time-locking points. To investigate the effects at the disambiguation, averages were computed for 1000 msec after the onset of the

[2] The time-locking points for the two verbs *antwoorden* and *waarschuwen* (see footnote 1) were determined on the basis of individual length differences. These indicated that by far the largest difference in length occurred from the second syllable on. Therefore, for these verbs the onset of the second syllable was chosen as time-locking point.

disambiguating verb. A period of 150 msec before each time-locking point was used as baseline.

Epochs with excessive EEG (>100 µV) and/or EOG amplitude (>75 µV) were excluded from the analyses. For the analyses of the CPS, transitive and intransitive conditions with a PB and transitive and intransitive conditions without a PB were taken together, because the first parts of the sentences (NP1, V1, and NP2) consisted of the same tokens. A mean of 43 trials (of a maximum of 56 trials, SD = 9.7) per participant and condition remained for SC items, and a mean of 32 trials (of a maximum of 40 trials, SD = 5.8) for OC items. For the analyses on the disambiguating verb, a mean of 27 trials (of a maximum of 28 trials, SD = 1.7) remained for SC items, and a mean of 19 (of a maximum of 20 trials, SD = 1.4) for OC items. On average, the number of removed trials did not differ more than one trial between the to be compared conditions.

To quantify the different ERP components, time windows were chosen on the basis of visual inspection and/or previous literature. For the analyses of the CPS, PB (PB, no PB) was entered as a critical factor. For the analyses on the disambiguating verb, Structure (transitive or intransitive) and PB were entered as critical factors. Initially, overall analyses were performed on the data of the SC and OC items together, with the additional critical factor Control (subject-control, object-control). For the overall analyses on the disambiguating verb we only report interactions of Control with the other critical factors. In the next step, we performed separate analyses for the SC and OC items. Two different types of multivariate repeated-measures analyses (e.g., Vasey & Thayer, 1987) were performed for all time-locking points. Next to the critical factor(s), the MANOVA for the midline electrodes included the factor Midline Electrode (Fz, Cz, Pz) and the MANOVA for the lateral electrodes included the factors Hemisphere (left, right), Region of Interest (ROI: anterior, posterior), and Electrode. The factors Hemisphere and ROI divided the electrodes into four quadrants with four electrodes each: left anterior (AF7, F7, F3, and FC3), right anterior (AF8, F7, F4, and FC4), left posterior (CP5, P3, P7, and PO7), and right posterior (CP6, P4, P8, and PO8). Three additional electrodes on either hemisphere (left: FT7, T7, C3; right: FT8, T8, C4) were not included in the overall analyses. For completeness, we do include these electrodes in the figures and report effects for these electrodes when follow-up analyses for the single electrodes are reported. In all analyses, we focus on effects including the critical factor(s) and only these are reported. For the figures only, and not for the analyses, the grand average waveforms were smoothed off-line using a 5 Hz lowpass filter.

Prosodic break. In Figure 2.2, grand average waveforms for all electrodes are presented, separately for the SC and OC items, time-locked to the onset of the last stressed syllable before the pause. Visual inspection suggests a clear Closure Positive Shift for both types of control items. The CPS starts almost immediately after pause onset (around 500 msec after stressed-syllable onset) and peaks around 500 msec after pause onset. On the basis of these observations a time window of 300 to 700 msec after pause onset, corresponding to roughly 800 to 1200 msec after onset of the stressed syllable, was chosen to analyze the CPS. Furthermore, a (small) reversed effect before the CPS can be observed at some electrodes (e.g., CP6). A window of 300 to 500 msec was chosen to analyze this effect.

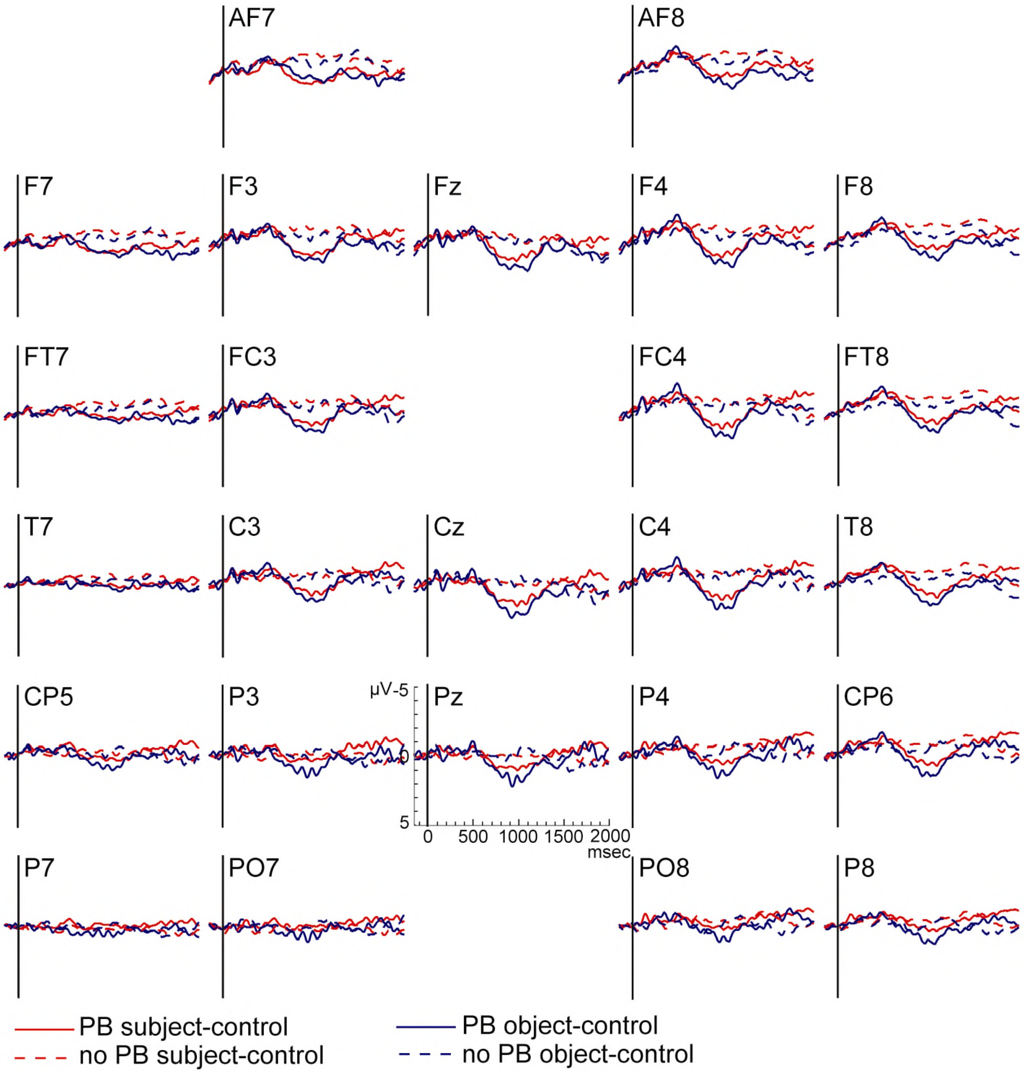

Figure 2.2 Grand average waveforms time-locked to stressed syllable onset, separately for SC and OC items. A CPS is present for the PB condition relative to the no PB condition in the 800-1200 msec window.

For the analyses of the CPS window with both SC and OC items, a main effect of PB was found in both the midline ($F(1,27) = 30.16$, $p < .001$) and the lateral analyses ($F(1,27) = 35.44$, $p < .001$). Furthermore, the lateral analysis yielded interactions between PB and the factors ROI ($F(1,27) = 9.89$, $p < .01$), Hemisphere and ROI ($F(1,27) = 7.30$, $p < .05$), Electrode ($F(3,25) = 7.75$, $p < .001$) and ROI and Electrode ($F(3,25) = 3.93$, $p < .05$). Separate analyses for the anterior and posterior ROIs yielded a main effect of PB for the anterior ROI ($F(1,27) = 31.53$, $p < .001$) and the posterior ROI ($F(1,27) = 17.46$, $p < .001$). For the posterior ROI, the analyses showed interactions between PB and Hemisphere ($F(1,27) = 6.56$, $p < .05$), and between PB and Electrode ($F(3,25) = 10.68$, $p < .001$). Separate analyses for the two smaller posterior ROIs revealed for the right posterior ROI an effect of PB ($F(1,27) = 36.67$, $p < .001$) and an interaction with Electrode ($F(3,25) = 9.64$, $p < .001$) and for the left posterior ROI an interaction with Electrode ($F(3,25) = 7.07$, $p < .01$). Analyses for the single electrodes showed a CPS in all electrodes (all ps $< .05$), except for left posterior electrodes P7 and PO7 (ps $> .30$).

In the overall analyses, no significant interactions between PB and Control were found (ps > .18) nor any interactions of these factors with Hemisphere, ROI, and/or Electrode (all ps > .10). However, Figure 2.2 suggests a difference in size of the CPS between the SC and the OC items (see e.g., Cz and P4)[3]. This CPS-modulation especially occurs around the peak of the CPS. Therefore, supplementary analyses were done for the four consecutive 100 msec epochs making up the CPS window. The lateral analyses showed an interaction between PB, Control and ROI for the 900-1000 window ($F(1,27) = 4.45$, $p < .05$) and for the 1000-1100 msec window ($F(1,27) = 5.66$, $p < .05$). Separate analyses for the anterior and posterior ROIs revealed a PB by Control interaction for the posterior ROI in the 1000-1100 msec window ($F(1,27) = 5.36$, $p < .05$). These analyses reveal a small but significant CPS-modulation with a smaller CPS for SC than for OC items[4].

To be certain that both SC and OC items showed a CPS, separate analyses were also performed. These showed the same general pattern for SC and OC items as in the overall analyses. In sum, for both SC and OC items we found a CPS that was broadly distributed over the whole scalp, however, somewhat attenuated in the left posterior part of the brain.

For the earlier window (300-500 msec), the overall analyses yielded interactions between PB and the factors Hemisphere ($F(1,27) = 5.84$, $p < .05$), Electrode ($F(3,25) = 4.74$, $p < .01$) and Hemisphere and Electrode ($F(3,25) = 4.33$, $p < .05$). Analyses for the right hemisphere yielded a marginally significant main effect of PB ($F(1,27) = 3.62$, $p = .068$) and for the left hemisphere a PB by Electrode interaction ($F(3,25) = 7.15$, $p < .01$). Follow-up analyses revealed an effect of PB for 4 right lateral electrodes (FT8, T8, CP6, P8, ps < .05). Separate analyses for the SC and OC items showed no effects at the level of the single electrodes for the SC items, whereas the OC analyses showed an effect of PB in the right hemisphere ($F(1,27) = 5.09$, $p < .05$). This early effect, opposite to the CPS, thus seemed to be mainly driven by the object-control items and showed a right hemispheric distribution.

Disambiguating verb. Figure 2.3 shows grand average waveforms for the SC items (panel A) and OC items (panel B) for all four conditions, time-locked to the onset of the disambiguating verb. Visual inspection of Figure 2.3 suggests a different pattern for the SC and the OC items. In panel A (SC items) a small N400 effect can be seen for the intransitive condition, both in the PB and in the no PB condition. The waveforms for the intransitive PB condition (solid red line) are more negative than those for the transitive PB condition (dotted red line), and the waveforms for the intransitive no PB condition (solid blue line) are more negative than those for the transitive no PB condition (dotted blue line). In contrast, visual inspection of panel B of Figure 2.3 (OC items) suggests an N400 effect, but only for the intransitive PB condition, as compared with the other three conditions. We analyzed the N400 using the standard 300-500 msec time-window.

[3] Grand average waveforms time-locked to sentence onset and pause onset descriptively show the same pattern (a larger CPS after OC than SC verbs), see section 2.6.

[4] Note that, regarding the acoustic analyses in the methods section of Experiment 1, this CPS-modulation could not be due to differences in the acoustic realization of the PB for the SC and OC items since no reliable difference in pause length between subject- and object control items were present and prefinal lengthening was more pronounced in the SC items than in the OC items, which goes in the opposite direction than the CPS-modulation.

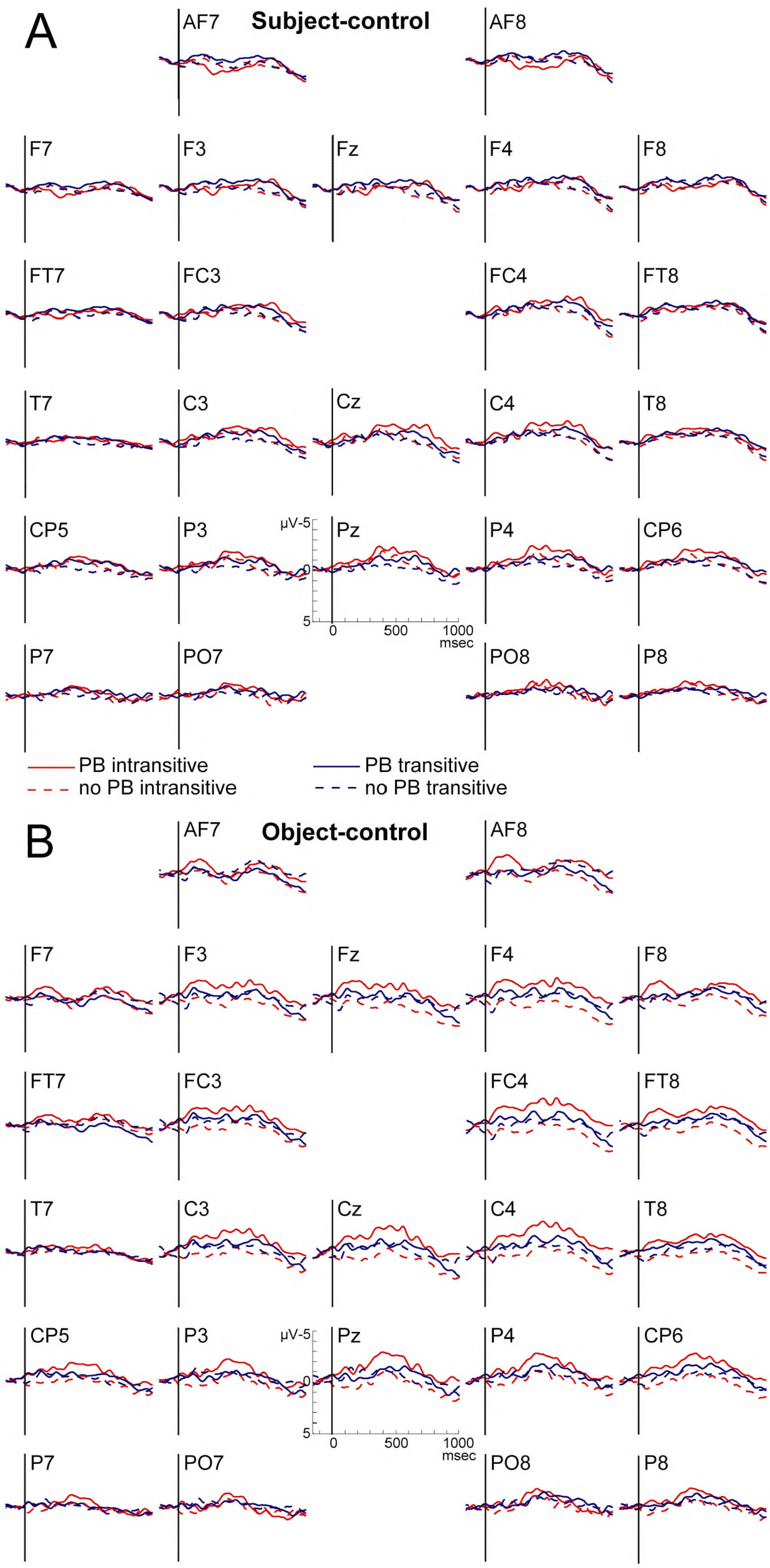

Figure 2.3 Grand average waveforms time-locked to the onset of the disambiguating verb (V2), for the SC items (panel A) and the OC items (Panel B), for the four different conditions. In panel A (subject-control) an N400 effect is present in the 300-500 msec window for both intransitive conditions relative to their corresponding transitive conditions. In panel B (object-control) an N400 effect is present in the 300-500 msec window for the intransitive PB condition relative to the transitive PB and the two no PB conditions.

The overall analyses yielded a three-way interaction between Control, PB, and Structure in the midline analysis ($F(1,27) = 4.29$, $p < .05$). This interaction only approached significance in the lateral analysis ($F(1,27) = 3.07$, $p = .09$). In the analyses for the SC items, the midline analysis yielded an interaction between Structure and Midline Electrode ($F(2,26) = 7.89$, $p < .01$) and the lateral analysis revealed an interaction between Structure and ROI ($F(1,27) = 8.89$, $p < .01$) and between Structure, ROI and Electrode ($F(3,25) = 7.57$, $p < .001$). Separate analyses for the two ROIs revealed a main effect of Structure for the posterior ROI ($F(1,27) = 5.87$, $p < .05$) and interactions between Structure and Electrode for the posterior ROI ($F(3,25) = 7.89$, $p < .01$) and anterior ROI ($F(3,25) = 3.41$, $p < .05$). Analyses for the single electrodes yielded an N400 effect at four posterior electrodes (P3, Pz, P4, CP6) and one separate electrode (C4) (ps < .05), confirming a typical centroparietal distribution with a trend towards a right-hemisphere dominance. Thus, a typical N400 effect was found for the intransitive as compared with the transitive disambiguating verb, both for the PB and no PB condition. Although the size of this N400 effect was small, varying between a mean of .29 and 1.00 μV for the different electrodes, the analyses show that it is statistically reliable.

In the analyses of the OC items, the midline analysis for the N400-window yielded a main effect of PB ($F(1,27) = 6.50$, $p < .05$) and a PB by Structure interaction ($F(1,27) = 7.28$, $p < .05$). The lateral analysis also revealed a main effect of PB ($F(1,27) = 4.73$, $p < .05$), and interactions between PB and Structure ($F(1,27) = 4.44$, $p < .05$) as well as between PB, Structure and Electrode ($F(3,25) = 5.06$, $p < .01$). The main effect of PB was presumably caused by baseline differences due to the presence of a CPS in the PB condition, but not in the no PB condition. Therefore, we did separate analyses for the PB and no PB conditions, to follow up the PB by Structure interaction, using only Structure as critical factor. For the PB condition, the midline analysis yielded a main effect of Structure ($F(1,27) = 9.84$, $p < .01$). The lateral analysis revealed a main effect of Structure ($F(1,27) = 6.15$, $p < .05$), as well as interactions between Structure and Electrode ($F(3,25) = 3.07$, $p < .05$) and Structure, Hemisphere, ROI, and Electrode ($F(3,25) = 3.99$, $p < .05$). Analyses for the lateral single electrodes showed an N400 effect for five left lateral electrodes (F3, CP5, P3, P7, and C3, ps < .05) and five right lateral electrodes (FC4, CP6, P4, P8, and C4, ps < .05). The N400 effect was thus widely distributed across the scalp and extended to anterior electrodes. For the no PB condition, no effects for the midline, or for the lateral analysis were found (all ps > .20). In sum, a broad N400 effect was found for the intransitive as compared with the transitive disambiguation, only for the PB condition.

2.2.3 Discussion

In line with our predictions and consistent with previous studies, a prosodic break gave rise to a CPS (e.g., Steinhauer et al., 1999; Kerkhofs et al., 2007), both for SC and OC items. In addition, we found a modulation of the CPS; it was larger after OC than after SC verbs. We will come back to this CPS-modulation in the General discussion of this chapter. The CPS had a broad scalp distribution but was most prominent on the right hemisphere and anterior part of the scalp. It started quickly after pause onset and peaked around 500 msec after pause onset. Apparently, in our data, the CPS started only *after* pause onset, in contrast with Steinhauer (2003) who reports an earlier onset latency of the CPS than the average pause onset. This difference can not be due to the use of different time-locking points, since, also with sentence onset as time-locking point (also used by Steinhauer, 2003), the present CPS started after average pause onset (see section 2.4). One explanation for this discrepancy in results could be differences in realization of the PB by the speakers in the different studies.

Before the CPS, a small, right lateralized reversed effect was found, which is most clearly seen in the OC items. This has also been found in some earlier studies (Kerkhofs et al., 2007; Pannekamp et al., 2005). It is unclear whether this early effect is part of the CPS complex. Future experiments will have to clarify this question. Finally, following Steinhauer (2003), one could argue that the positivity at the PB is not a real CPS but reflects the average of spread-out P2 components, in response to the onset of the acoustic signal after a pause. The following observations counter such a P2-interpretation. First, when filtering the grand average waveforms time-locked to sentence onset with a 1 Hz low pass filter, the P2 elicited by sentence onset disappeared while the CPS at the PB remained present. Second, a P2-interpretation would predict a less broad positivity when time-locking the ERPs to pause onset than to the other time-locking points, because the temporal jitter of the onset of potential P2s should be smaller. However, the positivity time-locked to pause onset looks even broader than for the other two time-locking points (see section 2.4). Third, the positivity starts before the average pause offset and thus can not be a response to the acoustic onset of the word following the pause.

At the disambiguating verb, we demonstrated different patterns of effects for SC and OC items. A general N400 effect for the intransitive as compared with the transitive V2 was found in SC items, whereas OC items showed such an 'intransitive N400 effect' only for the PB condition, and no effects when no PB was present. These results indicate that the PB affected the processing of the disambiguating V2, but this could only be shown for OC items.

Before turning to the General discussion, we would like to address two potential problems with the ERP results. First, as indicated in the results-section, the N400 effect at the disambiguating verb of the SC items was statistically reliable, but descriptively small in size. However, one has to bear in mind that descriptively large ERP effects are mostly found in sentences with an outright (semantic or syntactic) violation. In the present study, no outright violations were present, thus more subtle effects should be expected. This view is confirmed by other studies showing descriptively small but statistically reliable ERP effects in response to relatively subtle manipulations. Van Berkum, Van den Brink, Tesink, Kos, and Hagoort (2008) report that a mismatch between the semantic content of a sentence and the speaker information conveyed by the voice (such as *I think I am pregnant* in a male voice) elicited a small but significant N400 effect (0.56 μV in the 300-500 msec window, p. 584). They refer, in this context, to Nygaard and Lunders (2002) who speculate that constraints provided by tone of voice or prosody might, on average, be somewhat weaker than, e.g., constraints by lexical-semantic cues. Chwilla, Kolk, and Mulder (2000) demonstrated a small but statistically reliable N400 priming effect (maximally 1.14μV, p. 338) for mediated priming in which the prime relates to the target in two steps. Mecklinger, Schriefers, Steinhauer, and Friederici (1995) studied the processing of locally ambiguous sentences varying in semantic plausibility and found a statistically reliable N400 effect of about 1.1 μV (p. 488) for verbs that biased towards the garden path reading of the sentence as compared with the preferred reading.

A second potential problem concerns the possibility that the CPS might complicate the interpretation of the effects at the disambiguating verb. The CPS extends into the disambiguating region of the sentence. This indeed led to main effects of PB in the analyses at the disambiguating region for OC items. However, since we are not interested in main effects of PB, but rather in effects of Structure and the interaction between the two factors, this does not pose a problem as long as the size of the CPS does not differ systematically between sentences ending in intransitive and in transitive verbs. Since the same tokens were used for the first parts of the PB sentences (up till *te*, 'to') in the transitive and intransitive conditions and the same tokens were used for the first parts of the no PB sentences in the transitive and intransitive conditions, differences between transitive and intransitive conditions at the position of the PB are not very likely. To test this hypothesis empirically, we performed additional analyses for the CPS window including the factor Structure (transitive versus intransitive). For SC items with a PB, the size of the CPS between the transitive and intransitive condition differed only at one electrode (Fz). The no PB conditions differed at some left posterior electrodes (PO7, Pz, C3, P3 and P7). However, the N400 effect that we found in the SC items at the disambiguation showed a broader centroparietal distribution, with a right-hemispheric preponderance. For OC items with a PB, no differences in the size of the CPS were present between transitive and intransitive conditions. Therefore, the N400 effect for the intransitive PB condition can not have been induced by baseline-differences as a consequence of the CPS. The no PB conditions did differ at the offset of V1, at electrodes P8 and FT8. However, for these conditions we did not find any differences at the point of disambiguation. From these analyses we conclude that the pattern of results at the disambiguating verb was not caused by differences in the time epoch preceding this verb.

2.3 General discussion

2.3.1 Relation between FCT data and ERP data

The results of the FCTs and the ERP experiment show a clear dissociation for the OC items. For these items, a very strong off-line preference for intransitive completions (> 90%) was found. Even with a PB after V1, which should prevent the following NP2 from being regarded as the indirect object of this V1 and thus lead to the expectation of a transitive V2, the percentage of *intransitive* completions was still 78%. This stands in sharp contrast with the ERP data. The no PB condition revealed no N400 effect and thus no indication of the strong intransitive preference from the FCTs. Moreover, in the PB condition, an N400 effect for the intransitive disambiguating verb was found, indicating a transitive preference, which is the reverse of the FCT result.

Thus, the question arises why such a strong intransitive preference in the FCTs is not reflected in the on-line ERP data. In an FCT, completion with an intransitive verb requires regarding NP2 as the indirect object of V1. By contrast, completion with a transitive verb requires assuming an implicit indirect object of V1, since NP2 has to be the object of V2. This holds both for SC and OC items. However, if an OC item is completed with a transitive verb, the assumed implicit object of V1 also has to take on the role of the understood subject of V2, whereas this is not the case for SC items. Completion of OC items with a transitive V2 is thus the only case in which a subject for this V2 is not already present in the sentence, and thus will have to be imagined by the participant, assuming that production of a verb requires knowing the subject of that verb. In many cases, actively ‘inventing’ a subject in this way will be too much effort and thus will be avoided by the participants. By contrast, in the ERP experiment no active production is required. Participants only listen to the sentences and process them for meaning. It is possible to understand a sentence like (6) without imagining a subject for V2, for example as *The surgeon advised that the woman should receive support*.

Furthermore, apart from a general difference in preference, one might wonder why the PB had such a small effect in the FCT as compared with the ERP study. We think differences in task demands in the two types of experiments play a critical role. In the auditory FCT, participants have to listen to the sentence fragment, form an interpretation of this fragment, and then actively produce a possible continuation. The last two steps take several seconds. The prosodic information contained in the auditory sentence fragment might not remain active long enough to have a strong influence on the completion. In the ERP study, by contrast, the disambiguation immediately follows the ambiguous part of the sentence, so the prosodic information should be still active at the disambiguation.

These factors might thus explain the dissociation between the off-line FCT-results and the on-line ERP results. An important implication of this dissociation is that one should be very careful in generalizing results from off-line experiments to on-line processing.

2.3.2 ERP results at the disambiguating verb

Given the dissociation between the off-line fragment completion and on-line ERP data, what can we conclude from the ERP results about on-line processing of these sentences? First of all, the ERP results (as well as the off-line data) clearly indicate different processing patterns for SC and OC items. Therefore, in the following paragraphs, we will discuss them separately.

For the OC items, we found an N400 effect for the intransitive as compared with the transitive disambiguating V2 for sentences with a PB after V1, resembling the classical N400 in showing a bilateral centroparietal distribution. Since we cannot directly compare these results with the FCTs, we should consider the no PB condition as a baseline. In this condition, no effects were found, indicating that in on-line processing neither a transitive nor an intransitive V2 leads to processing difficulty. The N400 effect in the PB condition thus reveals that the PB affects the syntactic analysis pursued in OC items. The PB appears to block an interpretation of NP2 as indirect object of V1, which is eventually confirmed by a transitive, but disconfirmed by an intransitive verb.

For the SC items, an N400 effect for the intransitive as compared with the transitive disambiguating verb was found, resembling the classical N400 in showing a centroparietal distribution and being slightly larger for the right than for the left hemisphere. Since a similar N400 effect was found both for the PB and the no PB condition, we can not conclude that the PB has an effect on the syntactic analysis in SC items. A possible reason could be that the default preference for SC items does not adhere to the minimal attachment principle, as Steinhauer et al. (1999) assumed, but is reversed, namely transitive. If a default transitive preference exists for SC items, a PB after V1 confirms this preference, pointing in the same direction. This might be the reason why it does not have an apparent effect on top of the already present default preference.

There are several indications that such a default transitive preference in SC items indeed exists. First, in the (auditory) FCT-data an overall preference for a transitive completion was found. However, since the results for the FCT- and ERP experiments did not match for OC items, one should be careful, also for SC items, in interpreting the FCT-results in terms of consequences for on-line processing. However, as we argue above, the overwhelming intransitive preference in the FCT for OC items could be caused by the fact that the subject of V2, the verb that has to be produced in the FCT, is implicit in case a transitive V2 is produced. This argument does not hold for SC items, because the subject for V2 is available as NP1 both for an intransitive and a transitive completion. Therefore, there might be less reason to assume a difference in processing between the FCT- and ERP experiments for SC items. Second, in the ERP data an overall N400 effect for the intransitive as compared with the transitive disambiguation was found. This points to a preference for a transitive disambiguation, though one has to keep in mind that we are dealing here with a comparison between different verbs (transitive versus intransitive). It is possible that differences in length and/or semantics between these types of verbs have led to differences in N400 amplitude. However, since such a general 'intransitive' N400 effect was not present for OC items, we are confident that it was not caused by general verb-class differences between transitive and intransitive verbs. Third, the CPS-modulation at the position of the PB, could shed more light on this issue. If an SC verb elicits a preference for a transitive V2, this would fit with a PB after an SC verb. A recent study (Kerkhofs et al., 2007) revealed that the CPS was smaller in a situation where the PB is expected on the basis of information in the preceding discourse, than in a situation where there is no expectation. Extrapolating this to the present study, if a PB fits better after an SC than after an OC verb (due to the transitive V2 preference for SC verbs), the CPS should be smaller in the former than in the latter case. This is in line with our finding of a smaller CPS following SC than OC verbs.

What might be the reason for this default transitive preference in SC items? It is possible that SC verbs in general do not frequently have an overt indirect object. If that is the case, an NP after an SC verb will not so easily be regarded as its indirect object, but rather as the (direct) object of a later verb. This idea will have to be tested in future studies.

How do the present results relate to those obtained by Steinhauer et al. (1999)? Recall that Steinhauer et al. (1999) used only three of the four conditions of the present experiment and primarily focused on one comparison, namely between the conditions with a PB and a transitive or intransitive verb. They found processing difficulty (in the form of an N400-P600 sequence) for the intransitive as compared with the transitive disambiguating verb. Looking at the same comparison in the present results, we also find processing difficulty (in the form of an N400 effect) for the intransitive disambiguating verb, for both the SC and OC items. Steinhauer et al. (1999) regarded this result as a reversed garden-path effect, since they assumed that processing difficulty for the transitive disambiguating verb would be the default. The present ERP data show that this is not the case. For OC verbs, no processing difficulty for a transitive or intransitive disambiguation was found in the no PB condition, and for SC verbs processing difficulty in the no PB condition was found for intransitive verbs, suggesting a default preference in the opposite direction than assumed by Steinhauer et al. (1999). Thus, although the ERPs show that the PB does affect the preference for a transitive or intransitive disambiguating verb (at least in OC items), it appears that we are not dealing with a 'reversed garden path effect', as had been suggested by Steinhauer et al. (1999).

2.3.3 Interpretation of N400 effect and absence of P600 effect

As an indication of processing difficulty in the present study, we invariably found an N400 effect. N400 effects in response to violations of argument structure have been found before (e.g., Frisch, Hahne & Friederici, 2004; Friederici & Frisch, 2000; Osterhout et al., 1994), however accompanied by a P600 effect. N400 effects in these previous studies are explained, for instance, by the possibility that violations of thematic structure are inherently semantic in nature (Friederici & Frisch, 2000) or by assuming that this violation makes the sentence very hard to understand on a message level (Osterhout et al., 1994). Steinhauer et al. (1999) interpret the N400 effect as an indication of lexical re-access which is needed because the verb's argument structure is violated. A recently proposed model of sentence processing, the eADM (Bornkessel & Schlesewsky, 2006), explains the presence of N400 effects for these kinds of structures in the following way. Three hierarchical stages in sentence processing are proposed. In the second, most important stage, linking between arguments and verbs takes place. Problems in this stage can lead to an N400 effect. One could argue that in the present experiment, listeners are confronted with a linking problem. The PB leads the listener not to link NP2 to V1. Therefore, it is free to be linked to V2. However, the argument structure of an intransitive V2 is not compatible with this analysis. Therefore, NP2 has to be linked to V1.

This leaves the question why no P600 effect was elicited in the present study. Most studies on violations of argument structure (including Steinhauer et al., 1999) did find a P600 effect (sometimes next to an N400 effect). Steinhauer et al. (1999) interpret the P600 effect in their study as an indication of structural revision[5]. Following this interpretation, the absence of a P600 effect could indicate that participants did not reanalyze the sentence in the present study. Where might this difference come from? First, in contrast to our materials, the prosody in the sentences of Steinhauer et al. (1999) contained a major accent on NP2 in sentences with a PB (p. 195). For isolated sentences, it is possible that this prosodic information (which is not a part of the PB itself), in addition to the PB, could also block an interpretation of NP2 as the indirect object of V1, rendering an intransitive disambiguation even less acceptable. Second, case marking in German forced Steinhauer et al. (1999) to use only proper names (which are not case-marked in German), whereas in the present experiment the stimuli comprised full noun phrases indicating roles, and thus more imaginable scenarios. These scenarios might have focused participants' attention on the semantics of the sentence instead of the syntactic structure. Third, Steinhauer et al. (1999) presented comprehension questions after 20% of the sentences. This might have led participants to be more focused on the

[5] The P600 is generally regarded as an indicator of reanalysis or revision, though the form and function of this reanalysis are a matter of debate (e.g., Vissers, Kolk, Van de Meerendonk & Chwilla, 2008). However, it should be noted that others have questioned the exact role of the P600 as the sole indicator of reanalysis (see Kutas, Van Petten & Kluender, 2006 for a review).

syntactic structure and relations between arguments, because they had to prepare an answer to a possible question about these relations. By contrast, in the present study, participants' main task was to listen for comprehension. This might have lessened the need to understand the structure of the sentences, promoting semantic analysis. A recent study (Friederici, Von Cramon, & Kotz, submitted) supports this argument, also reporting an N400 effect, but no P600 effect, with a task (prosody judgment) that did not direct the participants' attention to the syntactic structure of the sentence, using the same stimuli as Steinhauer et al. (1999).

2.3.4 Conclusions

The present study reveals that items with subject- and object-control verbs are processed differently. Fragment completion tests indicated a strong preference for intransitive completions in OC items and a somewhat weaker preference for transitive completions in SC items. ERP data show a CPS-modulation as a function of the type of control verb. At the disambiguating verb of SC items, we found a general N400 effect for an intransitive disambiguation, both in sentences with and without a prosodic break. This contradicts the original assumption of Steinhauer et al. (1999) of a default preference based on minimal attachment. For OC sentences, a mismatch between a PB and a subsequent disambiguating verb elicited an N400 effect in contrast to a situation without a PB. This result reveals that prosodic information can be sufficient to determine the syntactic analysis of a sentence.

2.4 Supplementary analyses on the CPS for different time-locking points[6]

As indicated in section 2.2.2 of this chapter (Data-analysis of ERP data), we analyzed the CPS for three different time-locking points. In section 2.2.2 (Prosodic Break) we reported the analysis with 'stressed syllable' as time-locking point. Here, we present the analyses for the time-locking points sentence onset and pause onset (V1 offset). Against the background of these analyses, we will discuss the relative advantages and disadvantages of the three time-locking points.

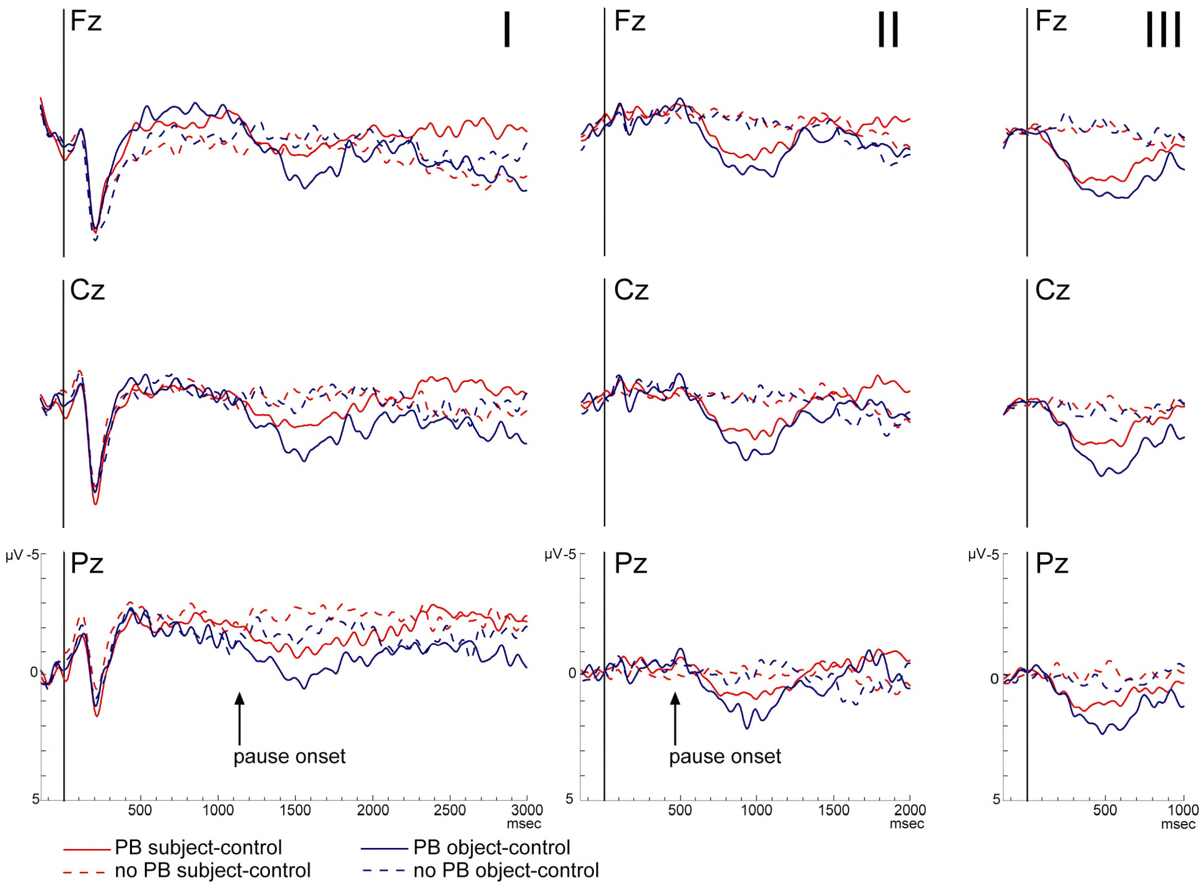

Figure 2.4 Grand average waveforms for the midline electrodes, time-locked to sentence onset (panel I), onset of the last stressed syllable before the pause (panel II) and pause onset (offset of V1; panel III), separately for the SC and OC items, for the PB and no PB conditions. A CPS is present for both SC and OC items for all time-locking points.

2.4.1 Results

For easy comparison between the three time-locking points, in Figure 2.4, we present grand average waveforms for the three midline electrodes, time-locked to the three different time-locking points. In Figures 2.5 and 2.6, we present grand average waveforms for all electrodes time-locked to sentence onset and pause onset, respectively. The corresponding grand average waveforms for the stressed syllable time-locking point are provided in Figure 2.2 (section 2.2.2). Visual inspection of the waveforms after (average) pause onset (indicated in

[6] In the article as it appeared in the Journal of Cognitive Neuroscience, Appendix B provided a summary of the results of the analyses at all three time-locking points, including Figure 2.4.

Figure 2.4 by a marker in panels A and B) suggests a clear Closure Positive Shift for all three time-locking points. In agreement with the analyses reported in the results section of this chapter for stressed-syllable onset, we chose a time window of 300-700 msec for pause onset and 1400-1800 msec for sentence onset to analyze the CPS. For all time-locking points this corresponds to about 300-700 msec after pause onset (see the arrows in Figure 2.4). In the waveforms a small CPS modulation is also visible for all three time-locking points (see Figure 2.4), in that the CPS seems larger for the object- than for the subject-control items.

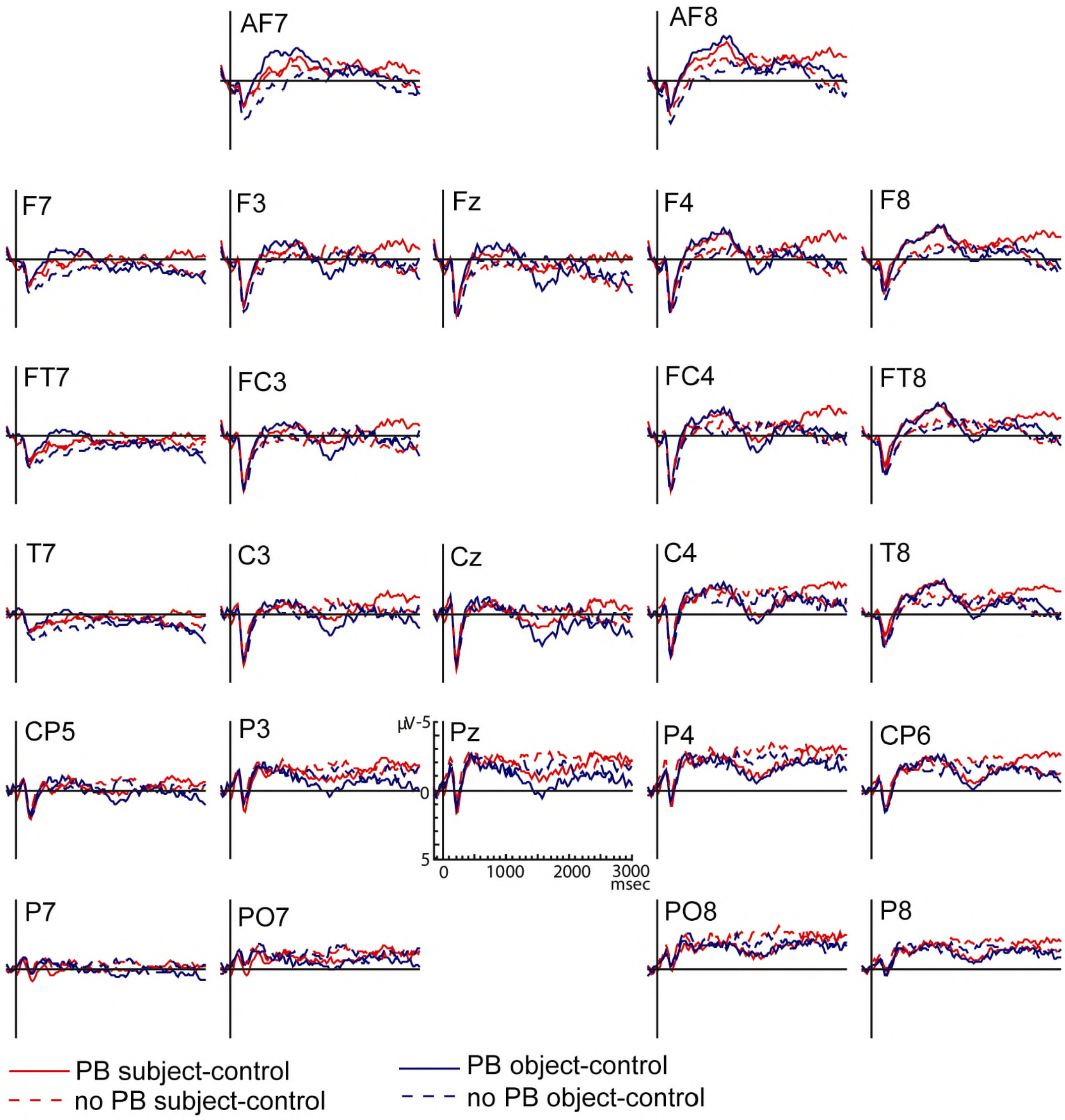

Figure 2.5 Grand average waveforms time-locked to sentence onset, separately for SC and OC items. A CPS is present for the PB condition relative to the no PB condition in the 1400-1800 msec window.

As described in the results section, we found a small negative effect preceding the CPS for stressed-syllable onset. Such a negative effect is also visible in the waveforms time-locked to sentence onset (Figure 2.4, panel A; Figure 2.5) at some electrodes. On the basis of visual inspection a window of 500 to 1000 ms was chosen to analyze this effect. For the waveforms time-locked to pause onset (Figure 2.4, panel C; Figure 2.6) the CPS starts almost immediately after the zero-point (pause onset) and thus no early negative effect is visible for this time-locking point.

Time-locked to sentence onset, analyses on the ERPs in the CPS-window (1400 to 1800 ms, or 300 to 700 ms after the average pause onset) yielded a main effect of PB for both the midline ($F(1,27) = 5.46$, $p < .05$) and the lateral ($F(1,27) = 6.65$, $p < .05$) analyses. Furthermore, a four-way interaction was present between PB, Control, Hemisphere, and Electrode ($F(3,25) = 3.64$, $p < .05$). Follow-up analyses did not reveal interactions between PB and Control for any of the single electrodes. Then we performed analyses for four 100 msec windows within the 1400-1800 msec window (as we did for stressed-syllable onset). These yielded, for the lateral analyses, interactions between PB, Control, Hemisphere, and Electrode from 1400 to 1700 msec ($ps < .05$) and between PB, Control, and Electrode from 1400 to 1600 msec ($ps < .05$). Separate analyses for the two hemispheres showed interactions between PB, Control, and Electrode for the right hemisphere from 1400 to 1700 msec ($ps < .05$) and from 1500 to 1600 msec for the left hemisphere ($p < .05$). However, no interactions between PB and Control were found for the single electrodes (all $ps > .10$). Thus, we found a CPS, but no reliable modulation by type of control item.

For the earlier window (500-1000 ms) the midline analysis revealed an interaction between PB and Midline Electrode ($F(2,26) = 4.56$, $p < .05$). The lateral analysis yielded a main effect of PB ($F(1,27) = 4.41$, $p < .05$), an interaction between PB and ROI ($F(1,27) = 13.46$, $p < .01$), and an interaction between PB and Electrode ($F(3,25) = 4.75$, $p < .01$). To follow-up the first of these two interactions, analyses for the separate ROIs indicated a main effect of PB for the anterior ROI ($F(1,27) = 11.97$, $p < .01$) and a PB by Electrode interaction for the posterior ROI ($F(3,25) = 6.91$, $p < .01$). However, follow-up analyses for the single electrodes revealed that the effect (more negative amplitudes for the PB condition) was only present at anterior electrodes, namely the midline electrode Fz ($p < .05$), six right anterior electrodes AF8, F4, F8, FC4, FT8, and T8 (all $ps < .05$), and three left anterior electrodes F7, AF7, and FT7 ($ps < .05$). This early, negative effect for PB was thus mainly distributed over the anterior ROI and slightly right lateralized. Furthermore, the overall analysis also yielded a four-way interaction between PB, Control, Hemisphere, and Electrode ($F(3,25) = 5.81$, $p < .01$). Analyses for the single electrodes showed only an interaction between PB and Control for AF7 ($p < .05$), pointing to a larger negative effect preceding the CPS for object-control than subject-control sentences.

Time-locking to pause onset, analyses for the CPS window (300-700 ms) yielded a main effect of PB in the midline analysis ($F(1,27) = 41.13$ $p < .001$). The lateral analysis also revealed a main effect of PB ($F(1,27) = 68.55$, $p < .001$) as well as interactions between PB and Hemisphere ($F(1,27) = 35.52$, $p < .001$), between PB and ROI ($F(1,27) = 27.62$, $p < .001$), between PB, Hemisphere, and Electrode ($F(3,25) = 3.27$, $p < .05$), between PB, ROI, and Electrode ($F(3,25) = 5.64$, $p < .01$), and between PB and Electrode ($F(3,25) = 14.67$, $p < .001$). Separate analyses for the two ROIs yielded a main effect of PB both for the anterior ($F(1,27) = 66.26$, $p < .001$) and the posterior ROI ($F(1,27) = 26.30$, $p < .001$). Follow-up analyses for the single electrodes revealed that a CPS was present at all electrodes (all $ps < .05$) except for PO7 and P7 ($ps > .45$).

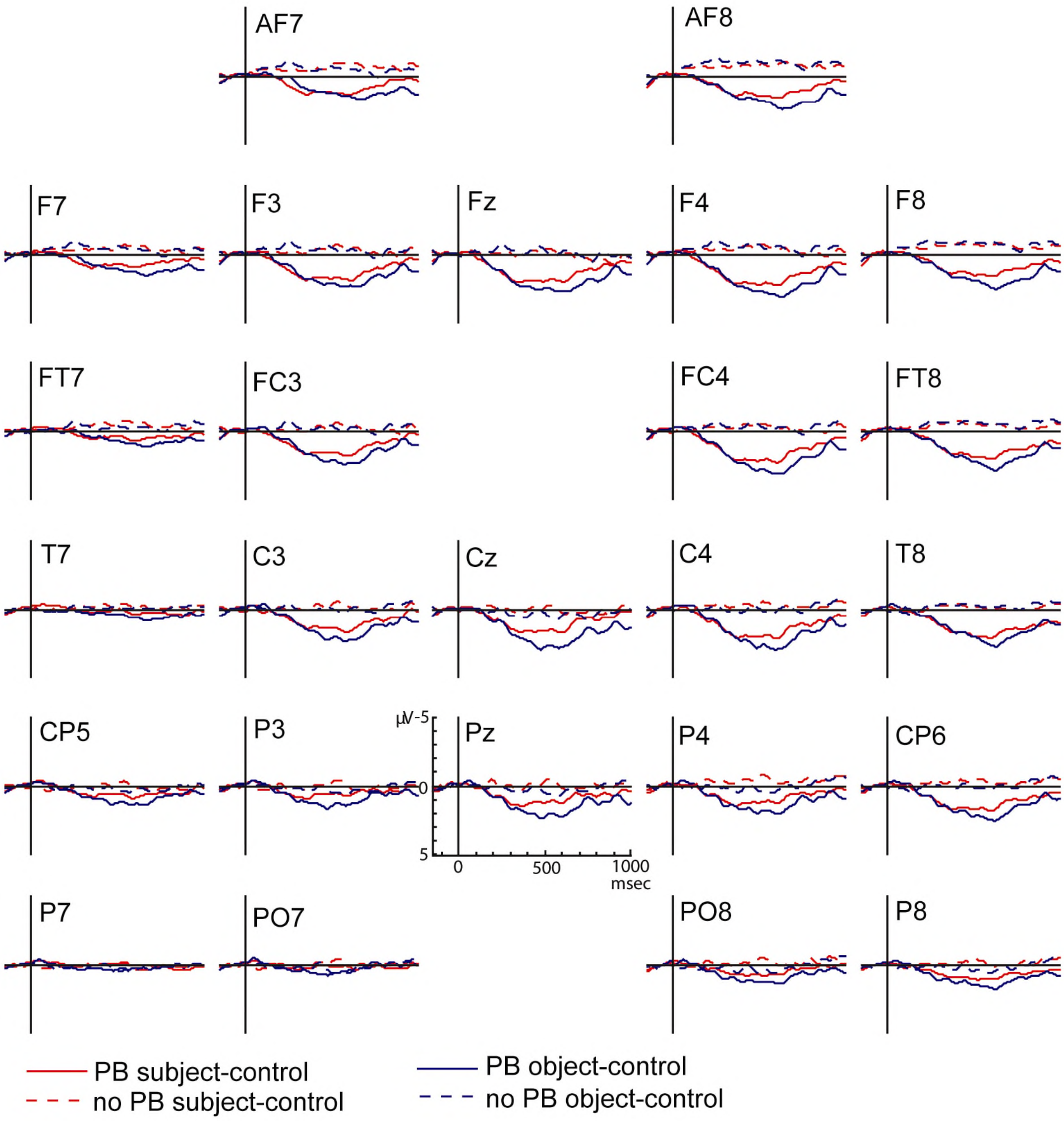

Figure 2.6 Grand average waveforms time-locked to pause onset, separately for SC and OC items. A CPS is present for the PB condition relative to the no PB condition in the 300-700 msec window.

In the main analysis also a four-way interaction was found between PB, Control, Hemisphere, and ROI ($F(1,27) = 5.27$, $p < .05$). No interaction between PB and Control was found in any of the four ROIs. However, when comparing the OC and SC items with a PB we found a main effect of Control in the midline analysis ($F(1,27) = 5.34$, $p < .05$), whereas we found no main effect of control comparing the SC and OC items without a PB (ps > .5). When we looked at separate 100 msec windows within the 300-700 msec window, no interactions between PB and Control were found (all ps > .05).

2.4.2 Discussion

In sum, the analyses for all three time-locking points revealed a widely distributed CPS, which indicates the robustness and reliability of the CPS. Descriptively, the CPS was larger for object-control than for subject-control items for all three time-locking points. However, statistically, this effect was not very reliable. Furthermore, a small negative effect preceding the CPS was found for sentence onset and stressed-syllable onset at some electrodes.

What can we conclude about the relative advantages and disadvantages of the three time-locking points? For sentence onset, a larger epoch had to be extracted from the EEG, which therefore contained more artifacts, and thus more trials had to be removed for this time-locking point, leading to a loss of data. Moreover, this time-locking point led to more jitter in the onset of the PB, leading to a less pronounced CPS than the other two time-locking points. Overall, for stressed-syllable onset we obtained the most focal-shaped CPS with the sharpest peak (see Figure 2.4). This suggests that the elicitors of the CPS are time-locked well for this intermediate time-locking point and there is not much jitter in the onset of these elicitors. Furthermore, a negative effect preceding the CPS was obtained using sentence onset and stressed-syllable onset. For pause onset, the CPS started immediately after the zero-point. If a negativity preceded it, this was positioned just before the CPS in the baseline interval. Since the waveforms are set to zero in this interval, this would lead to a distortion of the CPS.

Taking together the above considerations, we show that all three time-locking points lead to a robust CPS. Still, stressed-syllable onset appears to be both theoretically and practically the most appropriate time-locking point to analyze the CPS.

Chapter 3

The role of prosodic breaks and pitch accents in grouping words during on-line sentence processing

Abstract

The present study addresses the question whether accentuation and prosodic phrasing can have a similar function, namely to group words in a sentence together. Participants listened to locally ambiguous sentences containing object- and subject-control verbs, while ERPs were measured. In Experiment 1, these sentences contained a prosodic break, which can create a certain syntactic grouping of words, or no prosodic break. At the disambiguation, an N400 effect occurred when the disambiguation was in conflict with the syntactic grouping created by the break. We found a similar N400 effect without the break, indicating that the break did not strengthen an already existing preference. This pattern held for both object- and subject-control items. In Experiment 2, the same sentences contained a break and a pitch accent on the noun following the break. We argue that the pitch accent indicates a broad focus covering two words (see Gussenhoven, 1999), thus grouping these words together. For object-control items, this was semantically possible, which led to a ‘good enough’ interpretation of the sentence. Therefore, both sentences were interpreted equally well and the N400 effect found in Experiment 1 was absent. In contrast, for subject-control items, a corresponding grouping of the words was impossible, both semantically and syntactically, leading to processing difficulty in the form of an N400 effect and a late positivity. In conclusion, accentuation can group words together on the level of information structure, leading to either a semantically ‘good enough’ interpretation or a processing problem when such a semantic interpretation is not possible.

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Prosody is an aspect of language that is available explicitly only in spoken utterances. The present study investigates whether two prosodic devices, prosodic phrasing and accentuation, can group words in sentences together during on-line language processing. In research on the role of prosodic phrasing in auditory sentence processing (e.g., Kjelgaard & Speer, 1999; Pynte & Prieur, 1996; Warren et al., 1995), the general idea is that prosodic breaks can indicate where syntactic breaks occur in a sentence, and thus affect on-line sentence processing. A prosodic break or boundary (PB) consists of a pause, and prefinal lengthening and a boundary tone on the word preceding the pause (e.g., Kjelgaard & Speer, 1999). ERP studies have shown that syntactic processing can be affected by PBs (e.g., a PB can disambiguate a locally ambiguous sentence; Chapter 2: Bögels, Schriefers, Vonk, Chwilla, & Kerkhofs, 2010; Kerkhofs et al., 2008; Steinhauer et al., 1999) as well as by left-edge boundary tones (Roll, Horne, & Lindgren, 2009; in press) and by sentence-end intonation (Eckstein & Friederici, 2005; 2006). Prosodic phrasing, for example by a PB, thus can provide information about the syntactic structure of a sentence.

In contrast, accentuation has been mostly studied in relation to information structure. The distribution of pitch accents in a sentence can indicate which information is *new*, and which information is already mentioned, that is, *given*. Dahan et al. (2002), for example, used the visual world paradigm to show that accented nouns lead to early fixations on a new object, whereas unaccented nouns lead to early fixations on an already mentioned object (see also, e.g., Birch & Clifton, 1995). This issue has also been addressed using ERPs, showing processing difficulties when listeners encounter missing accents on new words and/or superfluous accents on given words (e.g., Heim & Alter, 2006; 2007; Hruska & Alter, 2004; Johnson et al., 2003; Magne et al., 2005; Toepel et al., 2007; see also Stoltherfoht, Friederici, Alter, & Steube, 2007 for ERP effects on implicit prosody during reading).

The emerging picture suggests that prosodic phrasing can signal syntactic boundaries while accentuation can indicate which information is new and should thus be in focus. These seem to be clearly different functions. As a result, research on the role of prosodic phrasing and research on the role of accentuation in sentence processing have developed quite independently. However, in the present study we argue that in a certain respect, both prosodic devices might also serve a similar function, namely to indicate which words in a sentence belong together more closely than others.

With respect to accentuation, a closer look at the linguistic literature on the relation between accentuation and focus shows that an accent on a given word does not necessarily define only this specific word as being in focus. Rather, under certain circumstances, the focus induced by an accent on a given word can be wider than this word, that is, the focus can spread out to adjacent lexical elements. See (1) and (2) for examples (see Gussenhoven, 1999).

1. a. Who died?
   b. What happened?
2. JOHNson died.

The question in (1a) leads to a focus only on the word *Johnson* in the answer in (2) since the verb *died* is mentioned in the question and is thus given. In contrast, the question in (1b) is more general, and thus all elements of the answer (2) provide new information and should be in focus. Nevertheless, answer (2), with only an accent on *Johnson*, is also a correct answer to the wide focus question in (1b) (as would be an answer in which both elements are accented). Thus, it appears that the accent on *Johnson* can not only signal a narrow focus for this specific word, but also a wide focus consisting of *Johnson* and the unaccented verb *died*.

Gussenhoven (1999) explains this observation with the Sentence Accent Assignment Rule (SAAR). SAAR states that an accent on a certain noun (such as *Johnson* in 2) can not only lend focus to this accented noun, but also to an adjacent unaccented predicate of which it is an argument (i.e., *died* in 2). In the case of such a wide focus consisting of more than a single word, a pitch accent on a word groups two or more words together in terms of information structure. Note that SAAR is a descriptive linguistic account of accentuation. It provides a rule of how to assign accents to elements in a sentence, when it is known which elements should be in focus and which syntactic relations exist between these elements. No explicit statements are made about what happens in on-line, left-to-right sentence *processing*. If one extrapolates SAAR to sentence processing, one can hypothesize that an accented argument and an adjacent unaccented predicate are grouped together by the listener as a verb and its argument, provided the listener assumes a broad focus spanning both words.

From this perspective, PBs and pitch accents can serve a similar function. They both signal which words belong together more closely than others, though at different levels: PBs at the level of syntactic structure, and pitch accents at the level of information structure. In the present study, we will address the question whether PBs and accents do have such a similar function in on-line processing of auditorily presented sentences.

If these devices indeed have such a grouping function, they should affect the processing of locally ambiguous sentences like the Dutch sentences in (3) and (4) (LT: literal, word-by-word English translation, T: English translation). These constructions have been used before to study the role of PBs in sentence processing (e.g., in German, by Steinhauer et al., 1999) and the same stimuli (in Dutch) were used in Chapter 2 (Bögels et al., 2010).

3. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te slapen ($V2_{intransitive}$)…
LT/T: *The surgeon (NP1) advised (V1) the woman (NP2) to sleep* ($V2_{intransitive}$)…

4. De chirurg (NP1) adviseerde (V1) de vrouw (NP2) te ondersteunen ($V2_{transitive}$)…
LT: *The surgeon (NP1) advised (V1) the woman (NP2) to support* ($V2_{transitive}$) …
T: *"The surgeon (NP1) advised (V1) [someone] to support* ($V2_{transitive}$) *the woman (NP2)."*

Note that, in contrast to English, in (4) the indirect object of V1 (*advised*) can be left implicit in Dutch. This implicit indirect object is indicated by *[someone]* in the English translation. Furthermore, the word order of the last two constituents in (4) is reversed in Dutch as compared with English. Therefore, in Dutch, (3) and (4) are ambiguous up to the disambiguating verb, V2. In (3), V2 (*to sleep*) is obligatorily intransitive, and thus NP2 (*the woman*) has to be indirect object of V1 (*advised*). In contrast, in (4), V2 (*to support*) is obligatorily transitive, and thus NP2 is the direct object of V2. A PB after V1 can separate V1 and NP2, thereby blocking an interpretation in which NP2 is the indirect object of V1. This should lead to problems at the intransitive disambiguating verb in (3), but not at the transitive disambiguating verb in (4). In the ERP study in Chapter 2 (Bögels et al.), a PB after V1 indeed led to an N400 effect at an intransitive disambiguating verb (as in (3)) relative to a transitive disambiguating verb (as in (4)), whereas no difference was found when the PB was absent. However, this was only found for so-called object-control items as in (3) and (4). In these sentences, V1 (*advise*) is called an object-control verb because its (indirect) object is the understood subject of the later verb, V2. In (3) the indirect object of V1 (NP2, *the woman*) is also the understood subject of V2; the woman should sleep. In contrast, in (4) the indirect object of V1 is left implicit. However, it is clear that this implicit indirect object is also the understood subject of V2; the person(s) receiving the surgeon's advice should also support the woman. This is different in so-called subject-control items, such as (5) and (6).

5. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben gespiekt ($V2_{intransitive}$)…
LT: *The pupil (NP1) confessed (V1) the teacher (NP2) to have cheated ($V2_{intransitive}$)…*
T: *The pupil (NP1) confessed (V1) to the teacher (NP2) to have cheated ($V2_{intransitive}$)…*

6. De leerling (NP1) bekende (V1) de leraar (NP2) te hebben opgesloten ($V2_{transitive}$)…
LT: *The pupil (NP1) confessed (V1) the teacher (NP2) to have locked up ($V2_{transitive}$)…*
T: *"The pupil (NP1) confessed (V1) to have locked up ($V2_{transitive}$) the teacher (NP2)."*

In these sentences, V1 (*confess*) is called a subject-control verb because its subject (*the pupil,* NP1) in both (5) and (6) is also the understood subject of V2 (*to lock up* or *to cheat*) (see Comrie, 1985 for a discussion of subject- and object-control verbs). For subject-control items, in Chapter 2 (Bögels et al.) we found an N400 effect for the intransitive relative to the transitive V2, but this N400 effect was present both in sentences with and without a PB. This result suggests that a general preference for a transitive disambiguating verb exists in these subject-control items. This preference thus guides listeners in the same direction as the PB would.

The present experiments focus on the question whether not only prosodic phrasing but also accentuation can affect the grouping of words in sentences. To investigate this question, we first manipulate the presence of a PB alone (Experiment 1), as in Chapter 2 (Bögels et al., 2010). The motivation for this replication is twofold. First, the comparison of the off-line sentence completion task (Experiment 1 of Chapter 2) with the on-line ERP results (Experiment 2 of Chapter 2) showed that the general preference for a transitive or intransitive disambiguation in these sentences is relatively unstable. Second, the filler sentences in the ERP experiment of Chapter 2 contained a manipulation of the presence versus absence of a PB, which might have led participants to pay special attention to PBs. In the present Experiment 1, we replace these filler sentences by filler sentences without a manipulation of the presence versus absence of a PB. Despite this change, we expect to replicate the results of Chapter 2 in terms of ERP results, especially regarding the conditions with a PB.

In Experiment 2, a pitch accent on NP2 is introduced, in addition to the PB after V1. This is pitted against a situation where both PB and pitch accent on NP2 are absent. As we argued above, on the basis of SAAR (Gussenhoven, 1999), such a pitch accent on NP2 can project focus to an adjacent predicate in a broad focus situation. Since the sentences are presented in isolation (as in Chapter 2), we assume that listeners will indeed adopt a broad focus; a narrow focus on only the accented element (i.e., NP2 in Experiment 2) would require a context in which the other elements are given.

For the focus projection of the accented NP2 to an adjacent predicate, there are two options. The first option would be for NP2 to project its focus to the preceding predicate, V1. However, the PB between V1 and NP2 should indicate that NP2 is not an argument of V1 (see Chapter 2). The second option is that the accented NP2 lends focus to the following (unaccented) predicate, V2, thus grouping NP2 and V2 together. This grouping, however, can only succeed if NP2 can be interpreted as an argument of V2.

Since subject- and object-control items differ with respect to the understood subject of V2 (see above), we derive the hypotheses for these two types of sentences separately. For object-control items (see (3) and (4)), a transitive V2 as in (4) (*to support*) should pose no problem because NP2 (*the woman*) can be incorporated as an argument of *support*, that is, as its direct object. In (3), V2 (*to sleep*) is intransitive and thus NP2 cannot be its object. Furthermore, syntactically, the infinitival clause (*to sleep*) has no overt subject. If listeners only regard the sentence in such a syntactic way, they will conclude that NP2 (*the woman*) cannot be an argument of *sleep* (V2) and therefore get into problems when encountering this V2 following an accented NP2. However, inspecting the semantics of the sentence more closely, NP2 is the *understood* subject of V2 (i.e., the woman should sleep). In other words, NP2, the indirect object of the main clause, controls the reference of the understood subject of V2, hence the term ‘object-control’ (see Comrie, 1985, p. 47-48). Therefore, semantically, *the woman* (NP2) can be interpreted as an argument of *sleep* (V2), namely as its understood subject. If listeners process the sentences in such a semantic way, the broad focus interpretation of the accent on *woman* (NP2) would fit both *support* (the transitive V2 in (4)) and *sleep* (the intransitive V2 in (3)). In terms of ERP results, the additional accent on NP2 in Experiment 2 should thus lead to additional processing costs for an intransitive relative to a transitive V2 if listeners adhere to a strict syntactic analysis. However, if they take into account the semantics of the broad focus interpretation of an accented NP2, no additional processing costs are expected.

For subject-control items, a transitive V2 in (6) (*to lock up*) again poses no problem, since the accented NP2 (*the teacher*) is V2’s direct object, fitting a broad focus interpretation. In (5), however, NP2 (*the teacher*) is not a possible argument for the intransitive V2 (*to cheat*): nor as its object, since V2 is intransitive, nor as its understood subject. Therefore, neither syntactically nor semantically does the intransitive V2 fit with the broad focus interpretation of an accented NP2. In terms of ERP results, this should lead to additional processing costs relative to a transitive verb. As there is, to our knowledge, until now no ERP study on this issue, we refrain from predictions in terms of the specific ERP signature of this potential additional processing cost. Likely options are a quantitative difference, such as a larger N400 effect, or a qualitative difference, such as for example an additional P600 effect.

Finally, in both experiments and for both types of items, we expect to replicate the finding of a Closure Positive Shift (CPS), a positive going ERP component, in response to the PB, relative to the sentences without a PB (e.g., Chapter 2: Bögels et al., 2010; Steinhauer et al., 1999).

3.1 Experiment 1

3.1.1 Methods

Participants. Participants were 43 right handed native speakers of Dutch without hearing problems, who received 8 euros per hour or course credit for their participation. All participants were students at the Radboud University Nijmegen. Fifteen participants were excluded from analysis because of excessive artifacts, mainly due to eye blinks. The remaining 28 participants (20 women, 8 men) had a mean age of 21.7 (range 18 to 26).

Materials. The experimental materials were slightly adapted as compared to Chapter 2 (Bögels et al., 2010). See Appendix I at the end of this thesis for the complete list of experimental items. Table 3.1 gives examples of the two types of experimental items (object-control items and subject-control items) in the four experimental conditions. The first verb (V1) in each sentence is a so-called control verb. In object-control items, the indirect object of the control verb (V1) is the understood subject of V2. In subject-control items, the subject (NP1) of the control verb (V1) is the understood subject of V2. We used all suitable control verbs that are available in Dutch (10 object-control and 14 subject-control verbs)[1]. All verbs were used in two different items, leading to a total of 48 experimental items (20 object- and 28 subject-control items).

Table 3.1 Examples of experimental items. Intonational phrases, separated by PBs, are indicated by square brackets. Literal, word-by-word English translations are given in italics. For the English translations, see examples 3 to 6.

		Object-control
A	PB, intransitive V2	[De chirurg adviseerde] [de vrouw te slapen] [voor de zware operatie.] *[The surgeon advised] [the woman to sleep] [before the heavy surgery.]*
B	no PB, intransitive V2	[De chirurg adviseerde de vrouw te slapen] [voor de zware operatie.] *[The surgeon advised the woman to sleep] [before the heavy surgery.]*
C	PB, transitive V2	[De chirurg adviseerde] [de vrouw te ondersteunen] [voor de zware operatie.] *[The surgeon advised] [the woman to support] [before the heavy surgery.]*
D	no PB, transitive V2	[De chirurg adviseerde de vrouw te ondersteunen] [voor de zware operatie.] *[The surgeon advised the woman to support] [before the heavy surgery.]*
		Subject-control
A	PB, intransitive V2	[De leerling bekende] [de leraar te hebben gespiekt] [tijdens het eerste uur.] *[The pupil confessed] [the teacher to have cheated] [during the first hour.]*
B	no PB, intransitive V2	[De leerling bekende de leraar te hebben gespiekt] [tijdens het eerste uur.] *[The pupil confessed the teacher to have cheated] [during the first hour.]*
C	PB, transitive V2	[De leerling bekende] [de leraar te hebben opgesloten] [tijdens het eerste uur.] *[The pupil confessed] [the teacher to have locked up] [during the first hour.]*
D	no PB, transitive V2	[De leerling bekende de leraar te hebben opgesloten] [tijdens het eerste uur.] *[The pupil confessed the teacher to have locked up] [during the first hour.]*

Each item occurred in the four conditions A-D, see Table 3.1. V2 was either obligatorily intransitive (conditions A and B) or obligatorily transitive (conditions C and D). Between V1 and NP2 a PB was present (conditions A and C) or absent (conditions B and D).

[1] In Dutch (and English) a few control verbs exist that can be ambiguous between a subject- and an object-control verb. However, in the present experimental sentences, the control verbs were always used in such a way that they were unambiguously interpreted as either subject- or object-control.

The auditory experimental materials were spoken by a female native speaker of Dutch and digitally recorded. She first read a written version of a sentence silently for herself and then read it out loud. She only produced the sentences in which the presence or absence of a PB was in line with the disambiguating transitive or intransitive V2 (B and C in Table 3.1), each three times. These recorded sentences were spliced at two positions, after NP1 and before the *te* ('to') of V2. The resulting three parts (NP1, V1 plus NP2, and the remainder of the sentence) were used to create the experimental conditions A to D. For each item, all four conditions contained the same token of NP1; in one half of the items NP1 was taken from a sentence with a PB and in the other half from a sentence without a PB. The second cross-spliced part (V1 plus NP2) was taken from one recorded token with a PB for conditions A and C and from one recorded token without a PB for conditions B and D. The last cross-spliced part (*te* until the end of the sentence) was taken from one recorded sentence with an intransitive disambiguating verb for conditions A and B and from one recorded sentence with a transitive disambiguating verb for conditions C and D.

Furthermore, two different types of filler items were used in the experiment. One type consisted of 60 simple high or low cloze sentences (adapted from Hagoort & Brown, 1994). The other type were 60 sentences containing locally ambiguous subject/object-relative clauses (adapted from Mak et al., 2002). All filler items were recorded twice and cross-spliced. Also, 16 additional sentences of the same structure as the experimental sentences and 16 of the same structure as the filler sentences were recorded and cross-spliced. Twenty of these were used in a practice block before the experiment and 12 as starter sentences at the beginning of each of the six experimental blocks (see procedure).

Acoustic analyses were performed on the experimental sentences to compare the conditions with and without a PB. Table 3.2 in section 3.4 presents the measurements and statistical results of these analyses. Here, we summarize only the main results. Visual inspection revealed qualitative differences in the pitch track of V1 between sentences with and without a PB. In both object- and subject-control items with a PB, a more or less pronounced pitch rise occurred on V1 before the pause. In sentences without a PB, a normal pitch accent or in some cases deaccentuation occurred on V1. The acoustic analyses revealed that V1 was lengthened in the PB conditions relative to the no PB conditions for both types of items. This lengthening occurred on all syllables but was most pronounced for the last stressed syllable of V1 and subsequent syllables. A pause was present between V1 and NP2 in the PB conditions whereas no pause existed in the no PB conditions. NP2 had a slightly larger pitch range in the PB than in the no PB conditions for both types of items; in subject-control items this was compensated by a slightly longer duration of NP2 in the no PB condition. However, these differences on NP2 were all very small (see section 3.4). In all conditions, a pause occurred after V2.

Design. The experiment had two subdesigns, one for the object-control items and one for the subject-control items. Both designs consisted of the two fully crossed factors PB (PB, no PB) and Structure (transitive V2, intransitive V2).

Four different lists were created. Each experimental item occurred in all four conditions in each list (4 x 20 object-control items and 4 x 28 subject-control items = 192 experimental items), but only once in each quarter of a list. The quarters in the four lists were counterbalanced in a Latin square design such that across lists each item occurred in all four conditions in each quarter. The conditions were counterbalanced within the lists and quarters in such a way that the conditions were distributed evenly over the quarters of the experimental lists. The 192 experimental items and 120 filler items were intermixed in a pseudorandom order. No more than three experimental or two filler items occurred in a row. The 312 sentences in each list were divided in 6 blocks of 52 sentences.

Procedure. Participants read an instruction to listen to the sentences for comprehension and to try to imagine what the sentences were about. Sentences were presented over headphones. A trial started with a 50 msec warning beep, followed by 450 msec of silence (with background noise from the recording) and the sentence. There was a 4000 msec interval between the end of a sentence and the next warning beep. The participants were instructed to restrict eye blinks to the beginning of this interval and to look at a fixation cross on a computer screen during the presentation of a sentence. This was trained during a practice block of 20 sentences which was repeated if necessary. Then, the 6 experimental blocks of 52 sentences each were presented, each preceded by 2 starter sentences.

After each block, the participants received a sentence recognition task. They had to indicate which of two written sentences had appeared in the previous block. This task ensured that attention was paid to the sentences. After this task, participants could take a short break before continuing.

Apparatus. EEG was recorded from 25 tin electrodes. Electrode positions were a subset of the international 10-20 system, consisting of three midline electrodes (Fz, Cz, and Pz) and 22 lateral electrodes (AF7/8, FT7/8, F7/8, F3/4, FC3/4, T7/8, C3/4, CP5/6, P7/8, P3/4, and PO7/8). This montage has been used in earlier auditory ERP studies (Kerkhofs et al., 2007; Bögels et al., 2010). During the recording, the left-mastoid served as reference, but re-referencing to the average of both mastoids occurred before the analysis. Vertical EOG electrodes above and below the right eye and horizontal EOG electrodes at the outer canthi were used to monitor eye blinks and eye movements. Impedance was kept below 5 kΩ for the EOG electrodes and below 3 kΩ for the EEG electrodes. EEG and EOG signals were amplified with a time constant of 8 seconds and a band pass filter of .05 to 100 Hz and digitized with a 16-bit A/D converter at a sampling frequency of 500 Hz.

Data-analysis for ERP data. The EEG data were first low-pass filtered with 30 Hz. Epochs were extracted for two different positions in the sentence, for the PB and for the disambiguating region (V2). For the PB, averages were computed from 150 msec before until 2000 msec after the onset of the last stressed syllable of V1, because at this position, the prefinal lengthening and the boundary tone start in the PB condition. This time-locking point, therefore, provides a good compromise between too much jitter between items in the onset of the pause of the PB (which would occur choosing sentence onset as time-locking point) and taking into account only the pause and no other components of the PB (which would occur choosing pause onset). See section 2.4 of Chapter 2 for a direct comparison of these time-locking points. We collapsed the data over the two levels of Structure (intransitive and transitive) for this time-locking point, because the sentences in these two conditions did not differ up to the disambiguating region (i.e., V2). For V2, averages were computed from 150 msec before until 1000 msec after its onset. The first 150 msec were used as a baseline.

Epochs containing excessive EEG (>100 μV) or EOG (>75 μV) amplitude were excluded from the analyses.

The preprocessed data were analyzed as follows. For the first time-locking point (PB), a time window of 800-1200 msec was chosen for analysis of the CPS (see Chapter 2), and for the second time-locking point (disambiguating verb), the standard N400 time window of 300-500 msec was used. Other time windows were chosen on the basis of visual inspection of the grand average waveforms and time course analyses of consecutive 100 msec windows. Separate analyses were performed for the object- and subject-control items. Critical factors were PB (PB, no PB) for the time-locking point of the PB (onset of stressed syllable of V1), and PB and Structure (intransitive, transitive) for the time-locking point of the disambiguating verb (onset of V2). For the midline electrodes, a repeated measures MANOVA was performed with the critical factor(s) and the factor Midline Electrode (Fz, Cz, Pz). For the lateral electrodes, the repeated measures MANOVA included the critical factor(s) and the factors Hemisphere (left, right), ROI (anterior, posterior), and Electrode (4 levels). Only interactions including a critical factor are reported. The factors Hemisphere and ROI divided the electrodes into four regions of interest with four electrodes in each region (left anterior: AF7, F7, F3, FC3; right anterior: AF8, F8, F4, FC4, left posterior: CP5, P3, P7, PO7; right posterior: CP6, P4, P8, PO8). This leaves six mid-lateral electrodes out of these analyses. If the distribution of an effect could not be shown via analyses of the separate ROIs and there were effects including the factor Electrode, separate analyses for all single electrodes were performed. The grand average waveforms presented in the figures were smoothed using a 5 Hz low pass filter. This additional filtering was not applied to the data entering the statistical analyses.

3.1.2 Results

Sentence recognition task. Out of the 28 participants, 27 correctly identified the sentence that they had heard from the two presented sentences after all 6 experimental blocks. One participant made one error.

ERPs to prosodic break. For the analyses of the CPS, after artifact removal, a mean of 36 trials (range 24 – 40 trials, SD = 3.6) remained per condition for object-control items, and a mean of 50 (range 42 -56 trials, SD = 4.0) for subject-control items, with no significant differences between conditions. Section 3.5 presents the grand average waveforms (Figure 3.4) for the PB and no PB conditions of the object- and subject-control items, time locked to the onset of the stressed syllable of V1 (just before the pause of the PB) and reports the statistical analyses on the CPS. For reasons of space, we report only the main conclusions of these analyses here. Both types of items showed a broad and robust CPS with a similar, somewhat right-lateralized distribution. Furthermore, the object-control items showed a negativity preceding the CPS that was broadly distributed across the scalp.

ERPs to disambiguating verb. For the analyses at the disambiguating verb, after artifact removal, a mean of 19 trials (range: 16 - 20 trials, SD = 0.9) per condition remained for object-control items, and a mean of 27 (range: 24 - 28 trials, SD = 1.1) for subject-control items, with no significant differences between conditions. Figure 3.1 displays grand average waveforms for a relevant subset of electrodes, time locked to the onset of V2 for all four experimental conditions, separately for object-control items (panel A) and subject-control items (panel B).

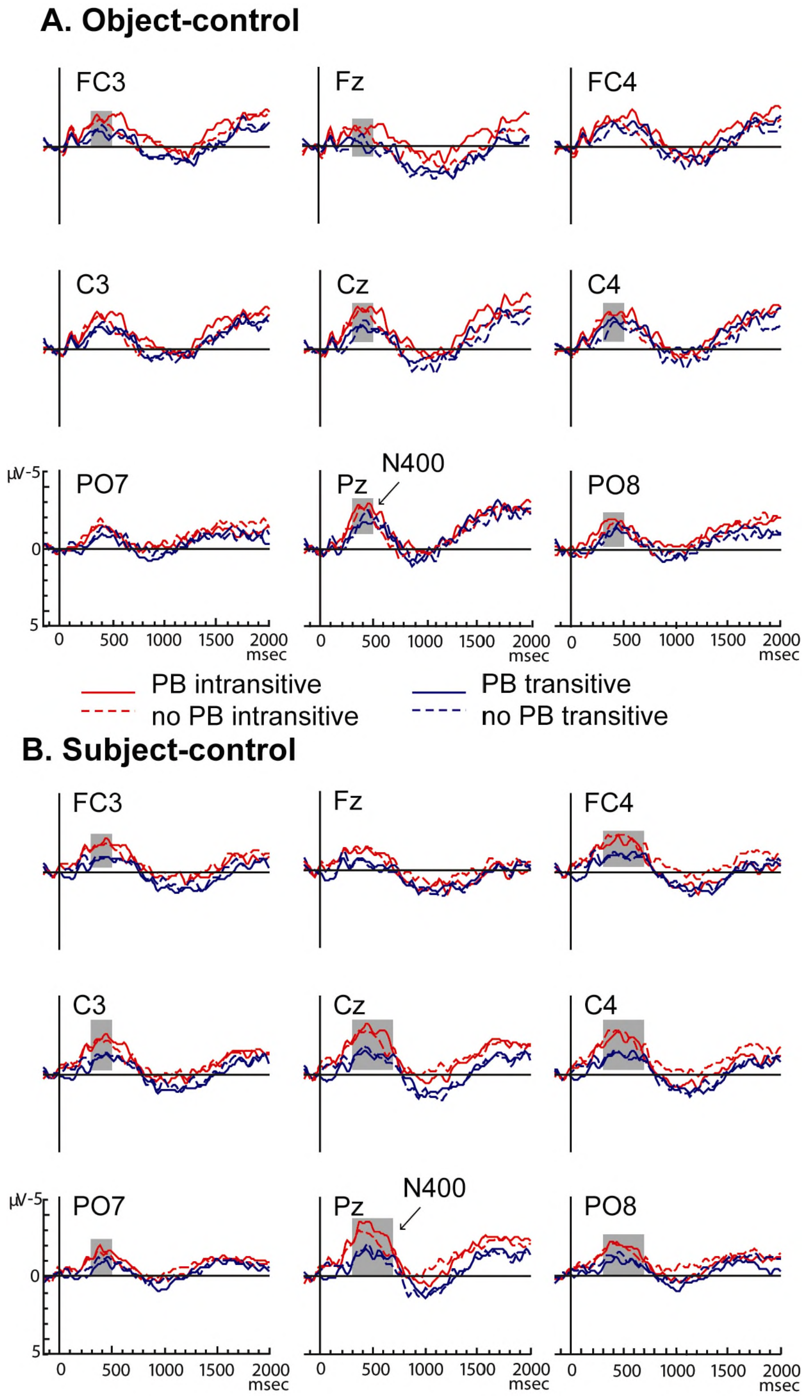


Figure 3.1 Grand average waveforms time locked to the onset of the disambiguating verb (V2) in Experiment 1 (for a subset of electrodes), for the object-control items (panel A) and the subject-control items (Panel B), for the four different conditions. Both panels show an N400 effect for both intransitive conditions relative to their corresponding transitive conditions.

Visual inspection suggests an N400-like effect for the intransitive conditions relative to the transitive conditions. At most electrodes, this effect seems to be prolonged up to 700 msec. This was confirmed by time course analyses of consecutive 100 msec windows. Therefore, in addition to the standard N400 window, we also analyzed the mean amplitudes for the 500-700 msec window. Throughout, we do not report main effects of PB, since these can be caused by confounds from the earlier presence or absence of a PB in the sentence.

The midline analysis for the object-control items yielded a main effect of Structure for the early (300-500 msec) window ($F(1,27) = 7.58$, $p < .05$) but no effects for the late (500-700 msec) window (ps > .06). For the early window, the lateral analysis showed a main effect of Structure ($F(1,27) = 5.36$, $p < .05$) and interactions between Structure, ROI, and Electrode ($F(3,25) = 3.64$, $p < .05$) and between Structure and Electrode ($F(3,25) = 3.50$, $p < .05$).
For the late window, this analysis yielded a four way interaction between Structure, Hemisphere, ROI, and Electrode ($F(3,25) = 4.00$, $p < .05$). Follow-up analyses for the early window revealed that the effect of Structure, reflecting a larger N400 for an intransitive V2 than for a transitive V2, was present over the central, right posterior, and some left anterior electrodes. For the late window, no reliable effects were found (all ps > .09).

The midline analysis for the subject-control items yielded a main effect of Structure for both the early ($F(1,27) = 13.98$, $p < .001$) and the late window ($F(1,27) = 7.35$, $p < .05$). For the early window, the lateral analysis showed a main effect of Structure ($F(1,27) = 14.49$, $p < .001$) and a Structure by Electrode interaction ($F(3,25) = 4.01$, $p < .05$). For the late window, a main effect of Structure ($F(1,27) = 6.12$, $p < .05$) and a Structure by PB by Hemisphere interaction ($F(1,27) = 8.92$, $p < .01$) were found. However, follow-up analyses did not reveal a Structure by PB interaction for any of the single electrodes (all ps > .07). The main effect of Structure, that is, a larger N400 amplitude for the intransitive than for the transitive condition, was broadly distributed across the scalp, but maximal at posterior electrodes for the early window. For the late window, the effect was mainly present centrally and over the right hemisphere. In sum, these analyses support a broadly distributed N400 effect for the intransitive as compared to the transitive V2 for object- and subject-control items.

3.1.3 Discussion

First, we replicated the finding of a CPS at the position of the PB, which has been reported in numerous previous studies (e.g., Chapter 2: Bögels et al., 2010; Steinhauer et al., 1999). The CPS was broadly distributed over the scalp with a tendency to be larger over the right hemisphere. Furthermore, a negativity preceding the CPS was present only for the object-control items.

At the disambiguating verb, V2, in Chapter 2 we found an interaction between Structure and PB for the object-control items, indicating that the N400 effect for intransitive V2s was present in the PB condition, but not in the no PB condition. The present experiment yielded a general intransitive N400 effect for the PB and no PB conditions. This difference between the present chapter and Chapter 2 suggests that for object-control items, listeners have a rather unstable preference for a transitive or intransitive disambiguating verb. This conclusion is in line with the divergence in results for the object-control items, found in Chapter 2 between the off-line sentence completion task (Experiment 1) and the ERP experiment (Experiment 2).

Due to this unstable preference, the processing of these sentences might be easily influenced by subtle external factors. For example, the present experiment and Experiment 2 of Chapter 2 used different filler items. In the latter study, the fillers also contained a manipulation of the presence of a PB, which could disambiguate the filler sentences, while the filler sentences of the present experiment did not contain a comparable manipulation. Therefore, the possibility to use the PB as a cue for disambiguation might have been emphasized by the filler sentences in Chapter 2, but not in the present experiment.

For the subject-control items, on the basis of the results from Chapter 2, a general N400 effect was expected for intransitive relative to transitive V2s, irrespective of the presence or absence of a PB. Indeed, we found a larger N400 at the intransitive than the transitive disambiguating V2, both for sentences with and for sentences without a PB. This N400 effect was broadly distributed over the scalp but somewhat larger for the posterior regions. The effect lasted longer than the standard 300-500 msec window and for several electrodes extended to the 500-700 msec time window. Such a longer duration of effects is typical for auditory presentation of language (Anderson & Holcomb, 1995).

3.2 Experiment 2

Experiment 2, as Experiment 1, again contrasted items with and without a PB. However, the items with a PB were now realized with a pitch accent on NP2. As argued in the introduction of this chapter, the pitch accent on NP2 induces a broad focus and thus an attempt to analyze NP2 as an argument of V2. For subject-control items, this turns out to be impossible for an intransitive V2 as NP2 can neither be subject nor object of V2, which might lead to additional processing difficulty for the intransitive V2. In contrast, for object-control items, NP2 can be the syntactic object of a transitive V2 and the understood subject of an intransitive V2. Therefore, if listeners use a semantically plausible analysis, the pitch accent on NP2 should reduce or eliminate the ERP effects for intransitive V2s found in Experiment 1.

3.2.1 Methods

Participants. Participants were 33 right-handed native speakers of Dutch without hearing problems. All were students at the Radboud University Nijmegen. They received 10 euro per hour or course credit for their participation. Because of excessive artifacts, 5 participants were excluded from the analyses. The remaining 28 participants (24 women, 4 men) had a mean age of 20.1 (range 18 to 23).

Materials. The materials consisted of the same items as in Experiment 1 (see Table 3.1 for examples), except for a few changes (see Appendix I at the end of this thesis). However, with respect to prosody, the items that contained a PB after V1 in Experiment 1, now contained both a PB after V1 and a pitch accent on NP2. The items that did not contain a PB after V1 were realized in the same way as in Experiment 1. The recording and cross-splicing procedures were the same as in Experiment 1, with one difference. The presence or absence of a pitch accent on NP2 might affect the prosody of NP1. Therefore, in Experiment 2, NP1 was not cross-spliced separately, and thus not the same token of NP1 was used in all four conditions of each item. In this way, we avoided a potentially unnatural prosody that might have occurred with the cross-splicing procedure used in Experiment 1.

Acoustic analyses were performed on the experimental sentences to compare the two prosodic conditions (see section 3.4, Table 3.3). NP1 had a somewhat longer duration (for both types of items) and a larger pitch range (only for subject-control items) in the sentences without a PB than in those with a PB. In contrast, the duration and the pitch range of NP2 were considerably larger in sentences with a PB and a pitch accent on NP2 than in sentences without these features. This held for both object- and subject-control items. Visual inspection revealed qualitative differences in the pitch track of V1 between the two prosodic conditions in both types of items. In sentences with a PB, a more or less pronounced pitch rise occurred on V1 before the pause, whereas in sentences without a PB, a normal pitch accent or deaccentuation occurred on V1. For object- and subject-control items, a prefinal lengthening effect was found for the last stressed syllable and subsequent syllables of V1 and a pause was present between V1 and NP2 in sentences with a PB and pitch accent on NP2, but not in sentences without these features. All conditions contained a pause after V2. Figure 3.3 in section 3.4 shows a sound waveform and pitch contour of two example sentences, one with a PB and pitch accent on NP2 and one without these features.

Design, procedure, and apparatus. The design, procedure, and apparatus were the same as in Experiment 1.

Data-analysis for ERP data. Data-analysis was the same as in Experiment 1, except for the late time window used to analyze the processing of the disambiguating verb (see below).

3.2.2 Results

Sentence recognition task. Out of the 28 participants, 21 correctly identified the sentence that they had heard out of the two presented sentences after all six experimental blocks. Seven participants made one error. Five of the errors were related to filler sentences and two were related to experimental sentences.

ERPs to prosodic break. For the analyses on the CPS, after artifact removal, a mean of 37 trials (range: 28 - 40 trials, SD = 3.4) per condition remained for object-control items, and a mean of 51 trials (range: 41 - 56 trials, SD = 4.3) for subject-control items, with no significant differences between conditions. Section 3.5 presents the grand average waveforms (Figure 3.5) for the PB and no PB conditions of the object- and subject-control items, time locked to the onset of the stressed syllable of V1 (just before the pause of the PB) and reports the statistical analyses on the CPS. Here, we only report the main conclusions of these analyses. Both object- and subject-control items showed a broadly distributed and robust CPS with a central maximum. Furthermore, a negativity preceding the CPS was found for the PB condition, both for the object- and subject-control items with a similar, right-lateralized distribution.

ERPs to disambiguating verb. Figure 3.2 presents grand average waveforms time locked to the onset of the disambiguating verb (V2) for all four conditions (for a subset of electrodes), separately for object-control (panel A) and subject-control items (panel B). Visual inspection suggests an N400-like effect for intransitive relative to transitive V2s in panel B (subject-control) at posterior electrodes. Panel B also shows a large difference between the two conditions with a PB and an accent on NP2 after 1000 msec. More specifically, a late positivity seems present for the intransitive as compared to the transitive V2 in sentences with a PB and an accent on NP2. We performed analyses for the standard N400 window (300-500 msec). For the late positivity, we chose an 1100-1400 msec window based on visual inspection of the grand average waveforms and time course analyses of 100 msec windows.

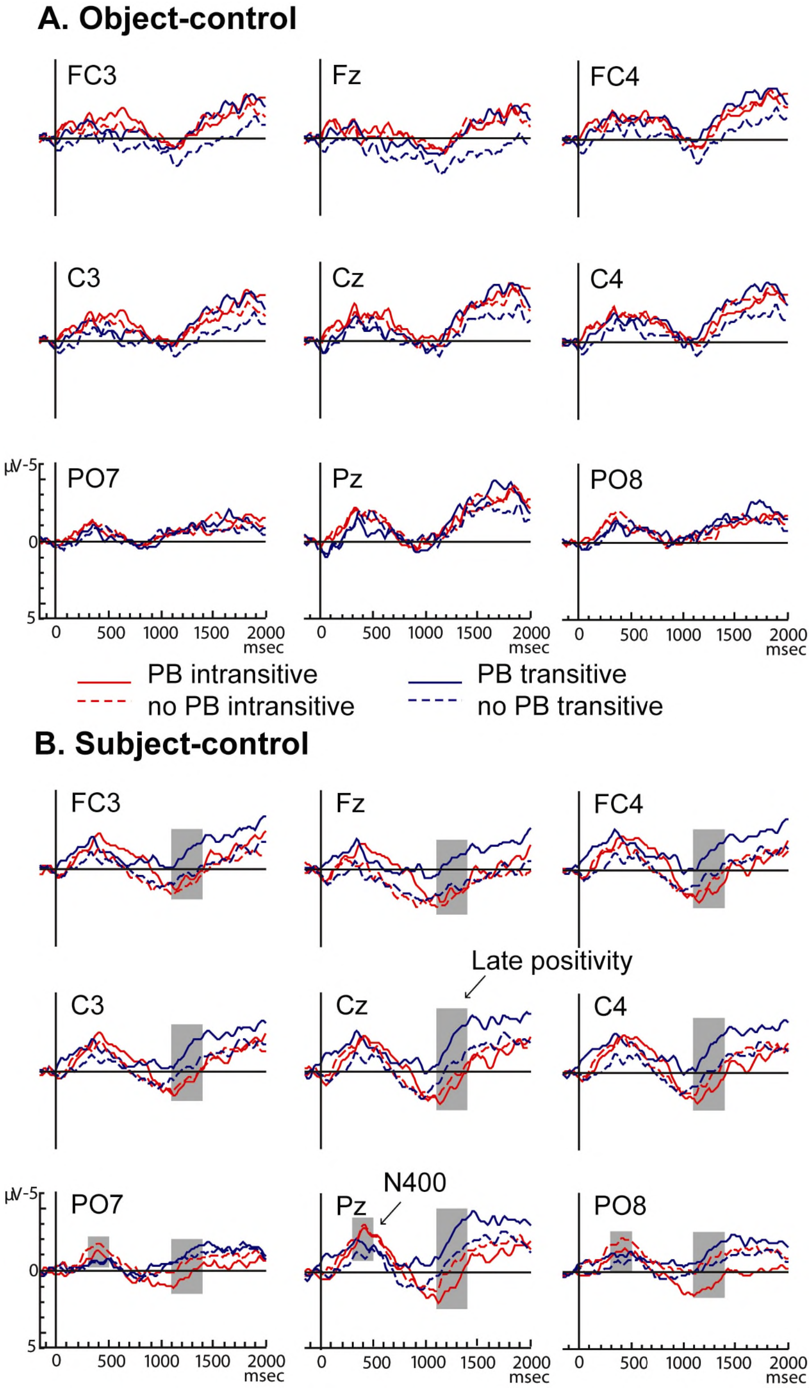


Figure 3.2 Grand average waveforms time locked to the onset of the disambiguating verb (V2) in Experiment 2 (for a subset of electrodes), for the object-control items (panel A) and the subject-control items (Panel B), for the four different conditions. In panel A (object-control) no reliable effects are present. In panel B (subject-control) an N400 effect is present for both intransitive conditions relative to their corresponding transitive conditions and a later positivity is present in the 1100-1400 msec window only for the intransitive PB condition.

Removal of artifacts before analyzing the N400 effect was based on an epoch from 150 msec before until 1000 msec after V2 onset. A mean of 19 trials (range: 16 - 20 trials, SD = 1.1) per condition remained for object-control items and a mean of 27 trials (range: 22 - 28 trials, SD = 1.3) for subject-control items, with no significant differences between conditions. For the N400 effect in the object-control items, the midline analysis did not show any effects (all ps > .20) and the lateral analysis yielded an interaction between Structure, Hemisphere, and ROI ($F(1,27) = 4.47$, $p < .05$), but none of the single electrodes showed an N400 effect (all ps > .07). For the subject-control items, we found trends towards an interaction of Structure by Midline Electrode in the midline analysis ($F(2,26) = 2.90$, $p = .07$) and towards an effect of Structure ($F(1,27) = 3.98$, $p = .06$) and a four way PB by Structure by Hemisphere by Electrode interaction ($F(3,25) = 2.86$, $p = .06$) in the lateral analysis. Follow-up analyses revealed no interactions between PB and Structure at the level of the single electrodes (ps > .08) but five centroparietal electrodes showed a larger N400 for the intransitive relative to the transitive conditions (P3, PO7, Pz, PO8, P8; ps < .05).

Thus, for the object-control items, no reliable differences between the conditions were found in the N400 time window. For the subject-control items, a small N400 effect for the intransitive relative to the transitive conditions was found with a standard centroparietal distribution.

Before analyzing the late time window, artifacts were removed based on an epoch from 150 msec before until 2000 msec after V2. A mean of 18 trials (range: 12 - 20 trials, SD = 2.1) per condition remained for object-control items and a mean of 26 trials (range: 17 - 28 trials, SD = 2.6) for subject-control items, without significant differences between conditions. For the object-control items, there were no significant differences in the 1100-1400 msec window (ps > .12). In contrast, the analyses for the subject-control items for this window yielded a main effect of Structure ($F(1,27) = 10.55$, $p < .01$) and a Structure by PB interaction ($F(1,27) = 7.15$, $p < .05$) in the midline analysis. The lateral analysis yielded a main effect of Structure ($F(1,27) = 10.10$, $p < .01$) and an interaction between Structure and Electrode ($F(3,25) = 3.07$, $p < .05$). Furthermore, an interaction was found between Structure and PB ($F(1,27) = 5.72$, $p < .05$), as well as interactions of these two factors with Hemisphere ($F(1,27) = 6.04$, $p < .05$), with ROI ($F(1,27) = 5.41$, $p < .05$), with Electrode ($F(3,25) = 4.51$, $p < .05$), and with ROI and Electrode ($F(3,25) = 4.85$, $p < .01$). Separate analyses for the no PB conditions did not show any effects of Structure (all ps > .16). In contrast, analyses for the PB conditions showed a main effect of Structure in the midline ($F(1,27) = 24.91$, $p < .001$) and lateral ($F(1,27) = 17.03$, $p < .001$) analyses as well as interactions between Structure and Electrode ($F(3,25) = 8.22$, $p < .001$) and between Structure, ROI, and Electrode ($F(3,25) = 6.46$, $p < .01$) in the lateral analysis. Follow-up analyses showed that this late positivity for the intransitive as compared to the transitive V2s in sentences with a PB and a pitch accent on NP2, was widely distributed across the scalp, but maximal over the posterior region.

To summarize the results at the disambiguating verb for Experiment 2, for subject-control items, we found a small N400 effect for the intransitive as compared to the transitive V2, in both prosodic conditions. In addition, only for the sentences with a PB and an accent on NP2, a late positivity was obtained for the intransitive as compared to the transitive V2. For object-control items, no effects were observed, neither in the N400 window, nor in the late window.

3.2.3 Discussion

In Experiment 2, we introduced a pitch accent on NP2 in addition to the PB and compared this condition to one without these prosodic cues (no PB and no pitch accent on NP2). We again found a broadly distributed CPS in response to the PB, which was largest at the central electrodes. A small, right-lateralized negativity preceded the CPS for both object- and subject-control items.

At the disambiguating verb of object-control items, no evidence for a reliable difference between the processing of intransitive and transitive V2s was found. For subject-control items, Experiment 2 replicates the N400 effect at the disambiguating V2 found in Experiment 1 of Chapter 2. Again, an intransitive V2 elicited a larger N400 than a transitive V2, and this was the case for sentences with a PB and without a PB. The N400 effect was present in the standard 300-500 msec window and showed the typical centroposterior scalp distribution. However, in contrast to Experiment 1 (and Experiment 2 of Chapter 2), the N400 was followed by a late positivity (time window: 1100-1400 msec) for the intransitive relative to the transitive disambiguating verb. This effect was only present for the subject-control items with a PB and a pitch accent on NP2, and absent for the subject-control items without these two prosodic features. In the General discussion of this chapter we will show how these results fit with our extrapolation of SAAR (Gussenhoven, 1999) proposed in the introduction.

3.3 General discussion

The present study addressed the question whether two different prosodic devices, a prosodic break and a pitch accent, can have a similar function, namely to group words in a sentence together. A PB can have such a function as it can be taken as an indication of a syntactic break, and it is meanwhile well established that this is the case (e.g., Chapter 2: Bögels et al., 2010; Kerkhofs et al., 2007; Steinhauer et al., 1999). For pitch accents, a similar function is less obvious, and has not yet been documented. However, as we argued in the introduction of this chapter, a pitch accent can introduce a broad focus interpretation, such that an accented argument and an unaccented adjacent predicate are grouped together. Such a broad focus interpretation, in turn, requires that the predicate and the argument can be integrated successfully, that is, that the predicate has an open slot for the (accented) argument. Before turning to a detailed discussion of the results concerning this question, we will briefly discuss the ERP effects at the PB.

3.3.1 Effects at the PB

Both experiments replicated an ERP effect elicited by the PB, the Closure Positive Shift (CPS; e.g., Chapter 2: Bögels et al., 2010; Kerkhofs et al., 2007; Steinhauer et al., 1999). The CPS was broadly distributed, somewhat more right-lateralized in Experiment 1 and more central in Experiment 2. The amplitude, timing, and distribution were similar for object- and subject-control items. The CPS was preceded by a negativity. In Experiment 1, this negativity was only significant for the object-control items. In Experiment 2, it was present for both types of items, but restricted to the right hemisphere. Such a negativity preceding the CPS has been found in a number of previous studies (e.g., Kerkhofs et al., 2007; Pannekamp et al., 2005; Pauker et al., submitted), and in Chapter 2 we also found a right lateralization of the effect.

The effect often starts early. In the present experiments, it started about 300 msec before the average pause onset, suggesting that the negativity is elicited by prosodic markers preceding the pause, such as prefinal lengthening and boundary tone. The functional significance of this effect, however, still has to be established.

3.3.2 Effects at the disambiguation: Object-control items

In Experiment 1, we found an N400 effect for intransitive V2s relative to transitive V2s for sentences with a PB and without a PB. In Experiment 2, which introduced a pitch accent on NP2 in sentences with a PB, by contrast, no N400 effects were found. Both patterns differ from the results of Experiment 2 in Chapter 2, which showed an N400 effect for intransitive V2s only for sentences with a PB.

This variability in results suggests that listeners do not have a stable preference for a transitive or intransitive V2 in object-control items. However, a closer look at the results of Chapter 2 and the present chapter reveals the following systematic pattern for on-line processing of object-control items. In conditions without a PB, we found either no difference between a transitive and an intransitive V2 (Experiment 1 of Chapter 2, and the present Experiment 2) or an N400 effect for an intransitive V2 (present Experiment 1), but we never obtained an N400 effect for transitive V2s. Thus, in on-line processing of object-control items, listeners appear to vary between 'no preference' and a preference for transitive V2s, while they never show a preference for an intransitive V2. Several variables might have contributed to the preference we find for the specific items in the present study. We will regard these in turn to see whether they could have played a role. First, as discussed in the introduction, the object-control items with a transitive and an intransitive V2 differ with respect to the presence of implicit arguments in the sentence. The items with an intransitive V2 do not contain any implicit arguments, because NP2 is both indirect object of V1 and understood subject of V2. In contrast, in the items with a transitive V2, the entity carrying these functions (indirect object of V1 and understood subject of V2) remains implicit. Because of this implicit entity, which might have to be filled in by listeners, one would expect the items with a transitive V2 to be more difficult to understand than those with an intransitive V2. However, if anything, the results indicate a larger N400 for the items with an intransitive V2. Second, parsing principles, such as minimal attachment and late closure (e.g., Pickering, Traxler, & Crocker, 2000) would predict that NP2, as soon as it is encountered, is incorporated in the current clause and is thus interpreted as an (indirect) object of V1. This fits with a preference for an intransitive V2 (see, e.g., Steinhauer et al., 1999, who assumed, but did not show, such a default analysis for parallel constructions in German), which is opposite to the preference that we find. Third, we looked at the frequency distribution of constructions with control verbs in a corpus of spoken Dutch (Corpus Gesproken Nederlands, 2006). This corpus analysis shows that the object-control verbs used in the present study took an explicit indirect object in 84% out of 215 sentences (see Section 3.6 for a detailed description). On the basis of these frequency results, one would also expect a preference for an intransitive V2. This is again in opposition to the present results, but in accordance with the results of the off-line fragment completion test (Experiment 1 of Chapter 2). Fourth, possible differences in, for example, general complexity, cloze probability, and frequency between the transitive and intransitive verbs that were used in the present study, could have played a role. A transitive verb can be regarded as requiring a more complex integration than an intransitive verb, since it has more argument slots, and therefore would be expected to elicit a larger N400. Furthermore, both the cloze probability (.12 for intransitive versus 0 for transitive V2s) and the frequency (1739 for intransitive versus 143 for transitive V2s, from the CELEX database, Baayen, Piepenbrock, & Van Rijn, 1993) are larger for the intransitive than for the transitive verbs used, also pointing in the direction of a reduced N400 for intransitive verbs. In summary, none of the above factors (implicit arguments, parsing principles, frequency of constructions, transitive-intransitive verb differences) can explain the preference for a transitive V2 or no preference for either V2, found for object-control items.

The most important comparison of the present study concerns items with a PB that do or do not contain a pitch accent on NP2. Object-control items with a PB and no pitch accent on NP2 consistently show a processing difficulty in the form of an N400 effect for intransitive as compared to transitive V2s (Chapter 2 and the present Experiment 1). This is in line with the fact that the PB (syntactically) separates V1 from NP2. However, Experiment 2 shows that this processing difficulty disappears when the sentences have a PB and a pitch accent on NP2. This pattern of results fits nicely with the considerations about pitch accents and broad focus interpretation (see the introduction of this chapter). The PB separates NP2 from V1, and thus NP2 cannot be the indirect object of V1. On hearing an intransitive V2, however, this turns out to be syntactically incorrect as NP2 cannot be a (direct) object of this intransitive V2 (and thus should be the indirect object of V1). But at the same time, the pitch accent on NP2 triggers a broad focus analysis according to which NP2 should be an argument of V2. Because V1 is an object-control verb, NP2 is the understood subject of V2 and can thus, in terms of argument structure, be analyzed as an argument (subject) of V2. Thus, we have two competing forces: The PB initially leads to the syntactically incorrect analysis of NP2 not being the indirect object of V1, but the broad focus interpretation induced by the pitch accent on NP2 triggers a strong tendency to analyze NP2 as an argument (the understood subject) of V2. The absence of any ERP effects at V2 suggests that, in this situation, speakers accept the interpretation resulting from the broad focus as 'good enough' without paying attention to the incorrect syntactic analysis of NP2. Thus, for example, a sentence like *The surgeon advised // the WOMAN to sleep* would be interpreted as "The surgeon gave the advice that the woman should sleep". This relates to the idea of 'good enough representations' put forward by Ferreira, Bailey, and Ferraro (2002). They argue that in certain circumstances, listeners interpret in particular difficult sentences (such as passives) using a semantic heuristic rather than a syntactic algorithm. In these cases, listeners do not necessarily obtain the exact true meaning of the sentence, but arrive at a good enough interpretation. It is conceivable that such a strategy was also used by the participants in the present Experiment 2, since the sentences are syntactically difficult. Moreover, participants did not perform an additional task, which would force them to analyze the sentences very thoroughly. Instead, they were asked to try to understand the sentences as they would do in daily life. Therefore, listeners might have used the pitch accent on NP2 to arrive at a coherent and thus 'good enough' interpretation of the argument structure of the sentence, without any specific processing difficulty. This clearly contrasts with sentences with a PB and no pitch accent on NP2

(Chapter 2 and present Experiment 1) which consistently showed processing difficulty at the intransitive V2.

In summary, at the disambiguating verb of object-control items without explicit prosodic cues, we found an N400 effect for the intransitive disambiguating verb. This indicates a default preference for a transitive disambiguation and thus a preference for syntactically coupling the disambiguating verb to the previous noun. The same result was found when a PB was present before the noun, showing that grouping by a PB alone did not strengthen this effect. When, in addition to the PB, the noun carried a pitch accent, this led to a stronger coupling between noun and disambiguating verb. Since in object-control sentences such a coupling was semantically possible for both the intransitive and the transitive disambiguating verb, the N400 effect disappeared, showing that listeners accepted a 'good enough' interpretation of the sentence.

3.3.3 Effects at the disambiguation: Subject-control items

For the subject-control items, we found a general N400 effect for the intransitive relative to the transitive disambiguating verb. This effect was not modulated by the prosody of the sentence; it was found for sentences without PB and accent on NP2 (Experiments 1 and 2), for sentences with only a PB (Experiment 1), and for sentences with a PB and an accent on NP2 (Experiment 2). These results replicate those found in Chapter 2 and suggest that listeners have a reliable and strong preference for a transitive V2 in subject-control items, which is also in line with the results of the off-line fragment completion experiment in Chapter 2 (Experiment 1). We will first consider whether the variables discussed above for object-control items can account for the reliable preference found for subject-control items. First, parsing principles such as minimal attachment and late closure, as explained above, point in the opposite direction. Second, when we searched in a corpus of spoken Dutch (Corpus Gesproken Nederlands, 2006) for the subject control verbs that we used in the present study, we found that in 94% of 154 sentences, the subject control verb did not have an overt indirect object (see Section 3.6 for a detailed description). If a subject control verb almost never takes an explicit indirect object, listeners would not expect an NP following a subject-control verb to fulfill this function. A transitive V2 fits best with this expectation, since NP2 is free to become direct object of V2. Thus, in the case of subject-control verbs, frequency of the construction is a possible explanation for the present ERP results. However, since this was not the case for object-control verbs, this factor cannot give a general explanation for the pattern of results in both subject- and object-control verbs. Third, regarding differences between transitive and intransitive verbs, again transitive verbs can be regarded as more complex (leading to a larger N400) than intransitive verbs. The cloze probability of the specific V2s used in the present materials did not differ between the two types of verbs in subject-control items (both .02) and the frequency was again larger for the intransitive than for the transitive verbs (1177 versus 416 respectively in the CELEX database, Baayen, Piepenbrock, & Van Rijn, 1993), which suggests a reduced N400 for intransitive verbs. In summary, none of the considered factors (parsing principles, frequency of constructions, transitive-intransitive verb differences) can account for the preference for a transitive verb in both types of control sentences. Future research will have to show which factors are responsible for this preference.

Again, as for the object-control items, the most important comparison for the subject-control items concerns the items with a PB that do or do not contain a pitch accent on NP2. Subject-control items with a PB consistently show an N400 effect at the intransitive as compared to the transitive V2 (Chapter 2 and the present Experiment 1). However, Experiment 2 shows that sentences with a PB and a pitch accent on NP2 do not show only this N400 effect, but in addition yield a large and broadly distributed positivity for intransitive V2s, maximal over posterior sites. This late positivity thus appears to be elicited by the combination of a PB and a pitch accent on NP2. An accent on NP2 can introduce a broad focus, that is, a focus on not only NP2, but on NP2 and an adjacent verb, such as V2. Such a broad focus requires that NP2 is an argument of V2. However, in the case of a subject-control V1 and an intransitive V2, NP2 cannot be an argument of V2, as NP1 is the understood subject of V2, and V2 is intransitive, excluding the option that NP2 is an object of V2. The resulting processing difficulty appears to be reflected in the late positivity.

An important language related ERP component is the P600. This positivity is generally found as a signature of a syntactic revision, around 600 to 800 msec. In our case, the positivity occurs much later, around 1100 to 1400 msec. However, earlier studies already found variability in the latency of the P600, especially in relation to prosodic mismatches (e.g., Astésano et al., 2004). This is also the case in a study that is very similar to the present study. Steinhauer et al. (1999) studied the processing of locally ambiguous German sentences with the same structure as the Dutch sentences of the present study. In the present context, the most important two conditions of their study are those items with a PB after V1 and a major accent on NP2 (p. 195). These items were disambiguated by a transitive or by an intransitive verb. The study by Steinhauer et al. also used object- and subject-control verbs as V1, but the data were collapsed across these two types of verbs. Steinhauer et al. found an N400 effect followed by a late positivity for the intransitive relative to the transitive disambiguating verb. The positivity was significant between 1200 and 1800 msec after the onset of the disambiguating verb, that is, in a similarly late time window as the positivity in the present Experiment 2. Steinhauer et al. refer to this positivity as a P600 effect and assume that it indicates a syntactic and prosodic revision. Although Steinhauer et al. do not discuss the late timing of the P600 effect, it is possible that prosodic revision, since it might involve subvocal corrections (p. 195), takes longer than syntactic revision. Although the present Experiment 2 is very similar to the study of Steinhauer et al., the results are difficult to compare, since Steinhauer et al. collapsed over object- and subject-control items. When collapsing the data of the present Experiment 2 over these two types of items, we obtain a similar pattern as Steinhauer et al., namely a biphasic N400-P600 pattern for an intransitive V2 relative to a transitive V2 in sentences with a PB and a pitch accent on NP2. However, the pattern of results that we found by taking into account the (semantic) differences between the two types of items shows that the late positivity is only carried by subject-control items with an intransitive V2. This is completely in line with the idea that the pitch accent on NP2 leads listeners to consider NP2 as a potential argument of V2 (which is impossible for an intransitive V2 in subject-control items).

Assuming that the late positivity indeed can be regarded as a P600, we can relate the present results to the Monitoring Theory of the P600 (e.g., Vissers, Kolk, Van de Meerendonk, & Chwilla, 2008). This theory states that a P600 will be elicited in the case of a strong conflict between an 'expected' and an actually encountered representation. In the present study, a pitch accent on NP2 triggers a broad focus interpretation and might thereby elicit an expectation for an adjacent verb that can take NP2 as its argument. Since the PB precludes the preceding verb as taking that function, the following word would then be expected to be a verb with this property, that is, a transitive verb. The P600 effect would then reflect the violation of this expectation. Alternatively, following a proposal put forward by Bornkessel and Schlesewsky (2006), the late positivity could be considered as reflecting a problem with generalized mapping, where several sources of information (such as prosodic pitch information and information about linking arguments to predicates) are brought together. Since in this case, these information sources cannot be integrated properly, the late positivity may reflect repair processes.

In summary, subject control items with and without a PB yielded an N400 effect at the intransitive relative to the transitive disambiguating verb. This result points to a default preference for a transitive disambiguation that is not strengthened by the grouping created by a PB alone. However, when a pitch accent was added on a preceding noun, this led to a combined N400 and P600 effect for the intransitive disambiguation. This shows that the disambiguating verb and the accented noun were grouped together in a broad focus domain created by the pitch accent. This grouping was both syntactically and semantically impossible for subject-control sentences with an intransitive disambiguating verb, leading to a strong processing difficulty.

3.3.4 Conclusion

Both prosodic phrasing and accentuation can group words, the former on the syntactic level and the latter on the level of information structure. When the grouping of words suggested by accentuation leads to a coherent semantic representation, this can lead listeners to pursue a 'good enough' semantic interpretation, while ignoring syntactic cues induced by prosodic phrasing. Conversely, the grouping of words by accentuation can lead to serious processing problems when it clashes with syntactic cues and does not allow for a coherent (good enough) semantic interpretation.

3.4 Supplementary acoustic analyses[2]

Tables 3.2 and 3.3 present the measurements and statistical analyses of the acoustic analyses of Experiments 1 and 2, respectively. We measured the length of NP1 (*NP1 length*), NP2 (*NP2 length*), the unstressed syllables (if present) preceding the stressed syllable of V1 (*V1 unstressed before*), the stressed syllable of V1 (*V1 stressed*), the unstressed syllables (if present) following the stressed syllable of V1 (*V1 unstressed after*), the pause of the PB following V1 in the PB conditions (*Pause1 length*) and the pause of the PB following V2 that was present in all conditions (*Pause2 length*). Furthermore, we measured the pitch range of NP1 (*NP1 pitch range*) and NP2 (*NP2 pitch range*).

Table 3.2 Means, SDs, difference values, and significance for the acoustic analyses of the experimental materials of Experiment 1, separately for the object- and subject-control items.

	Experiment 1		
	M_{PB} (SD)	$M_{no\ PB}$ (SD)	Difference
Object-control items			
NP1 length (msec)	578 (146)	578 (146)	-[1]
NP1 pitch range (Hz)	46(10)	46(10)	-[1]
NP2 length (msec)	514 (115)	521 (125)	-7 (n.s.)
NP2 pitch range (Hz)	35 (9)	29 (9)	6*
V1 unstressed before (msec)	160 (53)	143 (54)	17***
V1 stressed (msec)	440 (104)	261 (49)	179***
V1 unstressed after (msec)	201 (23)	94 (12)	107***
Pause1 length (msec)	420 (91)	-	-
Pause2 length (msec)	372 (72)	372 (72)	-[1]
Subject-control items			
NP1 length (msec)	573 (132)	573 (132)	-[1]
NP1 pitch range (Hz)	47(14)	47(14)	-[1]
NP2 length (msec)	542 (153)	561 (164)	-19**
NP2 pitch range (Hz)	36 (14)	31 (10)	5*
V1 unstressed before (msec)	140 (81)	131 (69)	9**
V1 stressed (msec)	435 (164)	268 (62)	167***
V1 unstressed after (msec)	276 (126)	158 (93)	119***
Pause1 length (msec)	413 (83)	-	-
Pause2 length (msec)	398 (82)	398 (82)	-[1]

*** $p < .001$. ** $p < .01$, * $p < .05$

[1] Due to the cross-splicing procedure, NP1 and Pause2 consisted of the same token in the PB and no PB conditions in Experiment 1.

[2] These supplementary acoustic analyses appeared in the article in the Journal of Cognitive Neuroscience as Appendix B.

Table 3.3 Means, SDs, difference values, and significance for the acoustic analyses of the experimental materials of Experiment 2, separately for the object- and subject-control items.

	Experiment 2		
	M_{PB} (SD)	$M_{no\ PB}$ (SD)	Difference
Object-control items			
NP1 length (msec)	528 (130)	552 (136)	-24***
NP1 pitch range (Hz)	63 (23)	72 (20)	-9 (n.s.)
NP2 length (msec)	515 (97)	477 (100)	38***
NP2 pitch range (Hz)	104 (36)	42 (16)	62***
V1 unstressed before (msec)	150 (57)	139 (52)	11*
V1 stressed (msec)	377 (89)	231 (41)	146***
V1 unstressed after (msec)	185 (23)	75 (11)	110***
Pause1 length (msec)	287 (95)	-	-
Pause2 length (msec)	321	321	-[1]
Subject-control items			
NP1 length (msec)	499 (97)	511 (102)	-12***
NP1 pitch range (Hz)	66 (24)	78 (19)	-12*
NP2 length (msec)	536 (125)	501 (126)	35***
NP2 pitch range (Hz)	112 (26)	49 (21)	63***
V1 unstressed before (msec)	153 (73)	147 (64)	6 (n.s.)
V1 stressed (msec)	372 (122)	234 (59)	138***
V1 unstressed after (msec)	184 (58)	104 (62)	79***
Pause1 length (msec)	277 (106)	-	-
Pause2 length (msec)	316	316	-[1]

*** $p < .001$. ** $p < .01$, * $p < .05$

[1] Due to the cross-splicing procedure, Pause2 consisted of the same token in the PB and no PB conditions in Experiment 2.

Figure 3.3 presents sound waveforms and pitch tracks for two example sentences of Experiment 2, providing qualitative information about the prosody in the condition with PB and pitch accent on NP2 and the condition without these features.

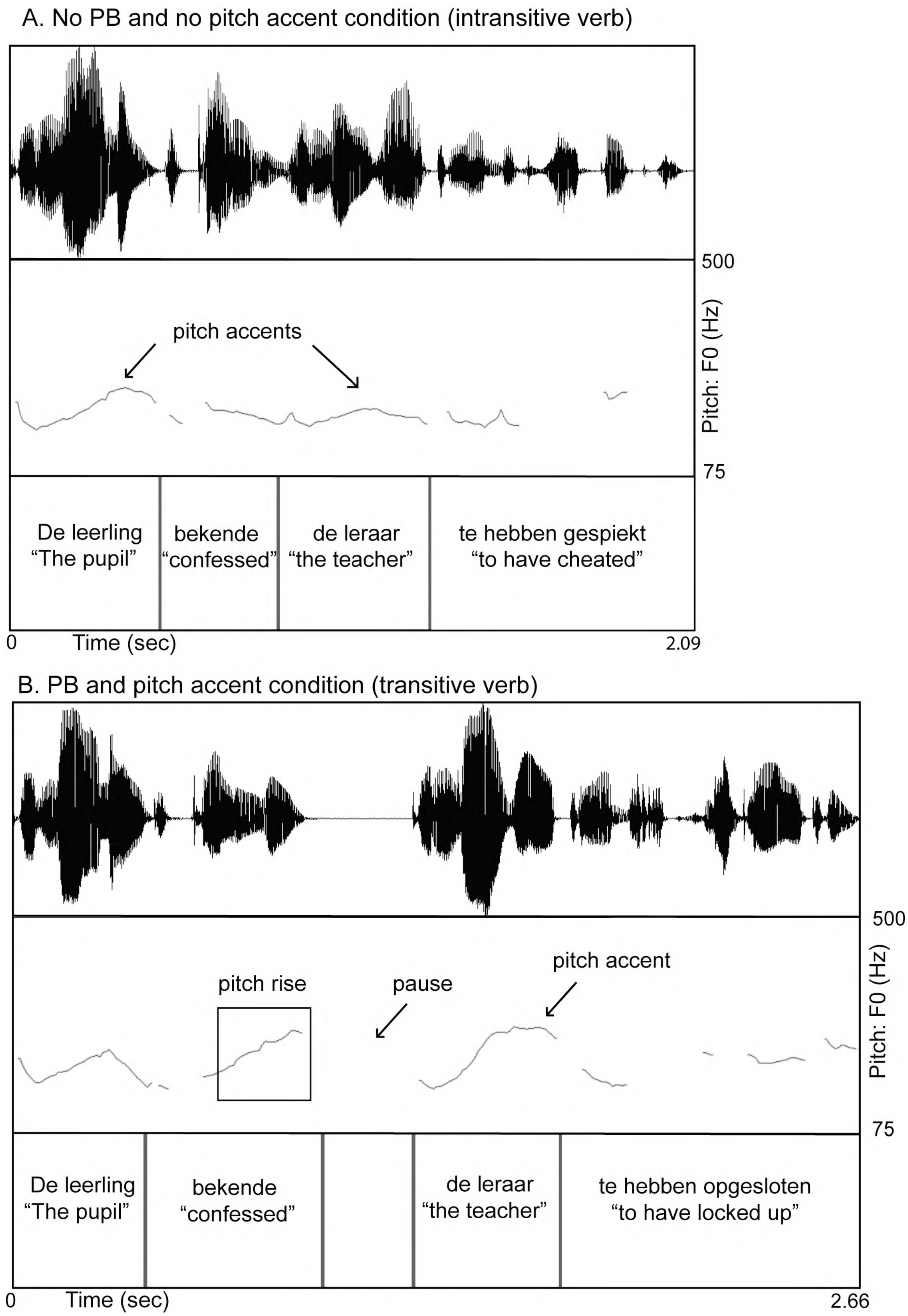


Figure 3.3 Sound waveforms and pitch tracks for two example sentences from Experiment 2. Panel A shows the no PB and no accent on NP2 condition with an intransitive V2 and panel B shows the condition with both a PB and a pitch accent on NP2 with a transitive V2.

3.5 Supplementary analyses of the CPS[3]

This section reports on the results of the analyses on the CPS of Experiment 1 and 2, which were briefly summarized in the results sections of this chapter (3.1.2 and 3.2.2, ERPs to Prosodic Break).

3.5.1 Experiment 1: Results at the prosodic break

Figure 3.4 presents grand average waveforms for the PB and no PB conditions of the object- and subject-control items time locked to the onset of the stressed syllable of V1. A large CPS with a broad scalp distribution was present for both types of items. Furthermore, a smaller negative effect seemed to be present preceding the CPS. We chose a 300-500 ms window on the basis of visual inspection to investigate this effect (see also Chapter 2).

For the object-control items in the 800-1200 msec window, a main effect of PB was present for both the midline ($F(1,27) = 14.27$, $p < .001$) and the lateral analyses ($F(1,27) = 11.28$, $p < .01$). The lateral analysis also revealed interactions between PB and Hemisphere ($F(1,27) = 6.15$, $p < .05$), between PB, ROI, and Electrode ($F(3,25) = 3.27$, $p < .05$), and between PB and Electrode ($F(3,25) = 6.34$, $p < .01$). Follow-up analyses revealed a broadly distributed CPS with a central maximum and a trend towards a right hemisphere dominance. For the subject-control items, the midline analysis for the 800-1200 msec window revealed a main effect of PB ($F(1,27) = 28.82$, $p < .001$) and a PB by Midline Electrode interaction ($F(2,26) = 7.77$, $p < .01$). The lateral analysis also showed a main effect of PB ($F(1,27) = 19.14$, $p < .001$), an interaction between PB, ROI, and Electrode ($F(3,25) = 5.89$, $p < .01$), and an interaction between PB and Electrode ($F(3,25) = 11.37$, $p < .001$). Follow-up analyses showed that the CPS was broadly distributed but most pronounced over the right hemisphere. Both types of items showed a broad and robust CPS with a similar, somewhat right-lateralized distribution. However, Figure 3.4 also suggests a small difference in the size of the CPS between object- and subject-control items in a small time window. To determine the reliability of this difference, we analyzed the object- and subject-control items together including the factor Control (object-control, subject-control), in time course analyses for consecutive 100 msec windows. These analyses showed a PB by Control interaction between 800 and 900 msec for the midline analysis ($p < .001$) and the lateral analysis ($p < .05$). Thus, a slightly larger CPS appeared to be present for the subject-control than the object-control items.

In the analyses on the negative effect preceding the CPS, the midline analysis for the object-control items in the 300-500 msec window showed a main effect of PB ($F(1,27) = 7.61$, $p < .05$) and the lateral analysis showed a main effect of PB ($F(1,27) = 9.67$, $p < .01$) and an interaction between PB, ROI, and Electrode ($F(3,25) = 6.29$, $p < .01$). Follow-up analyses revealed a broadly distributed effect, largest over the mid-lateral regions. The midline analysis and the lateral analysis for the subject-control items did not yield reliable effects for this window ($ps > .09$). The negative effect preceding the CPS was thus broadly distributed, but restricted to the object-control items.

[3] In the article as it appeared in the Journal of Cognitive Neuroscience, Appendix B provided grand averages of the CPS with only the midline electrodes and tables with the main results of the statistical analyses of the CPS of Experiments 1 and 2. Here, a full report of the analyses and grand averages of all electrodes is given.

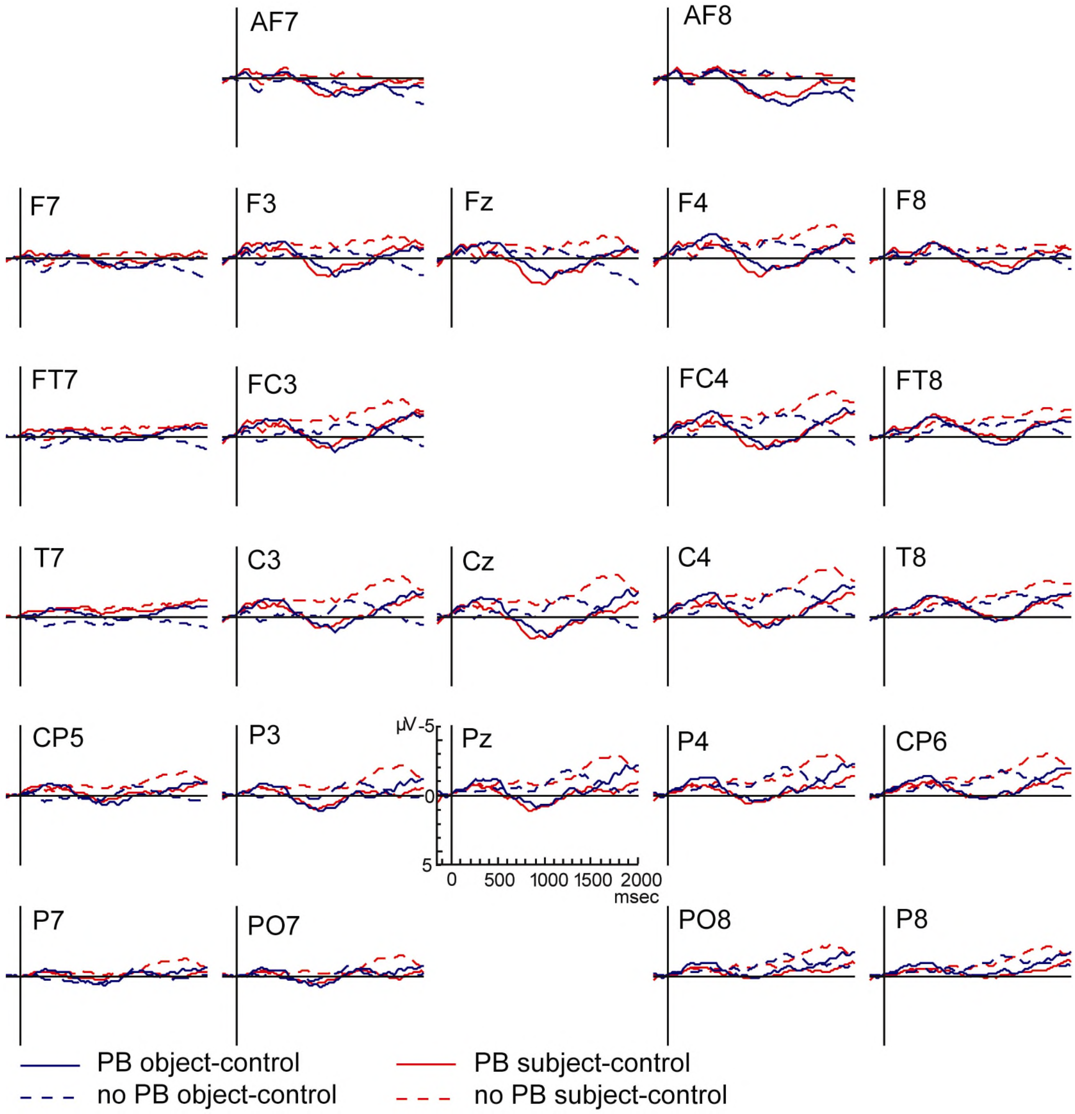


Figure 3.4 Grand average waveforms time locked to the onset of the stressed syllable of the control verb (V1) in Experiment 1, for object- and subject-control items. A CPS is present for the PB condition relative to the no PB condition in the 800-1200 msec window.

3.5.2 Experiment 2: Results at the prosodic break

Figure 3.5 presents grand average waveforms for the PB and no PB conditions time locked to the onset of the stressed syllable of V1, separately for object- and subject-control items. Visual inspection suggests a broadly distributed CPS and a substantial earlier reversed effect for both item types. Furthermore, a small modulation of the CPS seems present after the peak of the CPS.

For the object-control items, the midline analysis for the 800-1200 msec window yielded a main effect of PB ($F(1,27) = 14.01$, $p < .001$). The lateral analysis also showed a main effect of PB ($F(1,27) = 10.58$, $p < .01$) as well as an interaction between PB and Electrode ($F(3,25) = 8.32$, $p < .001$). Follow-up analyses revealed a broadly distributed CPS with a centroposterior maximum.

For the subject-control items, the midline analysis for the 800-1200 msec window yielded a main effect of PB ($F(1,27) = 7.53$, $p < .05$). The lateral analysis also showed a main effect of PB ($F(1,27) = 11.15$, $p < .01$) and interactions between PB, ROI, and Electrode ($F(3,25) = 4.37$, $p < .05$), between PB, Hemisphere, and Electrode ($F(3,25) = 3.02$, $p < .05$), and between PB and Electrode ($F(3,25) = 5.84$, $p < .01$). Follow-up analyses revealed a broadly distributed CPS, largest over central electrodes.

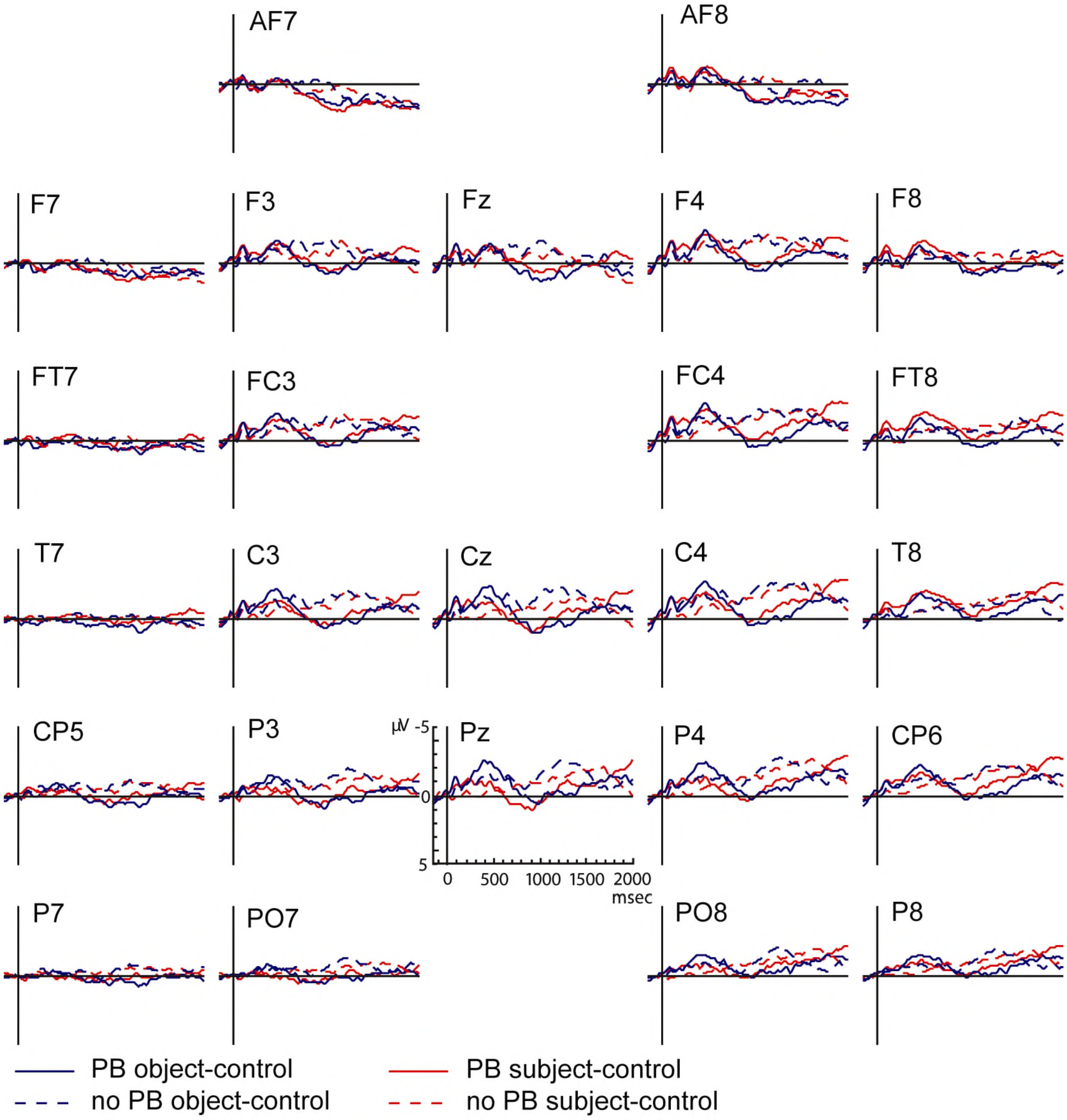


Figure 3.5. Grand average waveforms time locked to the onset of the stressed syllable of the control verb (V1) in Experiment 2, for object- and subject-control items. A CPS is present for the PB condition relative to the no PB condition in the 800-1200 msec window.

Although both types of items showed a broadly distributed and robust CPS with a central maximum, Figure 3.5 suggests a difference in the amplitude of the CPS in a small time window between 1000 and 1500 msec. Therefore, we performed time course analyses for 5 consecutive 100 msec windows spanning this epoch for the object- and subject-control items together, including the factor Control. For one of these windows (1200-1300 msec) the midline analysis revealed an interaction between PB and Control ($F(1,27) = 4.49$, $p < .05$) and between PB, Control, and Midline Electrode ($F(2,26) = 5.06$, $p < .05$) and the lateral analysis revealed an interaction between PB, Control, and ROI ($F(1,27) = 11.05$, $p < .01$).

Follow-up analyses confirmed a CPS modulation between 1200 and 1300 msec with a centroposterior distribution, indicating that the CPS was larger for object-control items than for subject-control items.

The negative effect preceding the CPS was analyzed with a 300-500 msec time window, as in Experiment 1. For the object-control items, we found a marginal interaction effect in the lateral analysis between PB, ROI, and Electrode ($F(3,25) = 2.51$, $p = .08$). Follow-up analyses showed five right lateral electrodes with a significant effect (FT8, T8, P4, CP6, and P8; ps $< .05$). For the subject-control items, the lateral analysis showed interactions between PB and Hemisphere ($F(1,27) = 6.92$, $p < .05$), between PB, Hemisphere, and Electrode ($F(3,25) = 5.62$, $p < .01$), and between PB, ROI, and Electrode ($F(3,25) = 3.44$, $p < .05$). For the right hemisphere, we found a main effect of PB ($F(1,27) = 6.56$, $p < .05$). No such effect was found for the left hemisphere. Thus, a negative effect preceding the CPS was found for the PB condition, both for the subject- and object-control items, with a similar, right-lateralized distribution.

3.5.3 Discussion

Both subject- and object-control items showed a robust CPS in response to the PB with a similar amplitude, timing, and distribution. However, a small difference in the size of the CPS was present between these items in a narrow window, but in different directions. In Experiment 1, the CPS was a bit larger for subject- than for object-control items, while in Experiment 2 the reversed pattern was found. Only the pattern in Experiment 2 corresponds to the direction of the CPS modulation found in Chapter 2. In both experiments, the CPS was preceded by a small negativity. In Experiment 1, this negativity was only significant for the object-control items. In Experiment 2, it was present for both types of items, but restricted to the right hemisphere.

These different patterns of results suggest that the CPS modulation is not very reliable. Small differences in the amplitude of the CPS might be caused by the size of ERP components preceding the CPS, such as the small negativity. Furthermore, the choice of the time-locking point to measure the CPS might also interact with this effect if the negativity preceding the CPS occurs around the baseline interval. Therefore, one should be very careful in interpreting differences in the size of the CPS. Note, however, that this especially holds when one compares the CPS elicited by different acoustic tokens of the PB, as in our comparison of subject- and object-control items. If one compares the exact same acoustic tokens of the PB, for example, in different discourse contexts (see Kerkhofs et al., 2007), the interpretation is much less complicated by the factors mentioned above.

3.6 Corpus study on subject- and object control verbs[4]

In the General discussion of the present chapter (sections 3.3.2 and 3.3.3), we briefly described the main results of an analysis based on a corpus of spoken Dutch (Corpus Gesproken Nederlands, 2006). In this section, we describe the corpus study in some more detail. The aim of the corpus study was to find out whether the (off- and on-line) preferences that we found in our ERP and fragment completion studies (Chapter 2 and the present study) would be correlated with frequency patterns in the auditory input. As in the ERP and fragment completion studies, we investigate subject- and object-control sentences separately (see the introduction of the present chapter for examples).

In Chapter 2 (Bögels et al., 2010), we performed a visual and an auditory off-line fragment completion study (presenting the sentences up to, but not including, the disambiguating verb, V2). For subject-control sentences, we found a small numerical (but non-significant) preference for transitive completions in the visual version, and a clear transitive preference in the auditory version, both for sentences with and without a PB after V1 (however, somewhat larger for sentences with a PB). The on-line ERP experiments (Chapter 2 and the present study) pointed in the same direction for subject-control sentences. Invariably, an N400 effect was found for the intransitive relative to the transitive disambiguating verb (V2), pointing to a transitive preference. Thus, both the on- and off-line studies all point to a parsing preference for a transitive V2 in subject-control sentences.

In contrast to this relatively stable direction of the preference for subject-control verbs, we found a much more variable preference for object-control verbs. In the off-line fragment completion experiments, we consistently found a preference for intransitive completions. However, in the on-line ERP studies, we either found no preference (no ERP differences between transitive and intransitive disambiguating verbs) or a transitive preference (N400 effect for the intransitive disambiguating verb).

Why do listeners prefer an intransitive or a transitive verb? The explanation can probably be found earlier in the sentence. For example, a preference for a transitive disambiguating verb (V2), as found for subject-control sentences, indicates that NP2 is interpreted as an object of V2. This can only happen if, in processing the earlier part of the sentence, NP2 was not interpreted as an object of V1. Why would listeners NOT assume that NP2 is an object of V1? The principle of late closure would go against this analysis, since it predicts that NP2 will be incorporated in the current clause, if possible. However, listeners might go against the late closure analysis if they do not expect V1 to have an indirect object, for example because this verb generally does not take (explicit) indirect objects. Conversely, if V1 generally does take an explicit indirect object, NP2 will be seen as this object and a preference for an intransitive V2 will arise.

To investigate this hypothesis, we searched for all the sentences in which the V1s from our study served as control-verbs in the spoken corpus of Dutch (Corpus Gesproken Nederlands, 2006). We used a spoken corpus, since most experiments in this thesis are in the auditory modality. More specifically, we addressed two questions. First, is the stable preference for a transitive V2 in subject-control items reflected in frequencies found in the

[4] This corpus study is not part of Bögels et al. (in press).

corpus? Second, what pattern do the object-control items show in the corpus; does it relate more to our off-line or to our on-line results?

3.6.1 Methods

The Corpus Gesproken Nederlands (2006; CGN) consists of a Dutch and a Flemish (Belgian Dutch) part. Only the Dutch part was selected since all the participants in our previous experiments were Dutch. Within the Dutch part of the corpus, sentences were selected in which the V1s from our previous studies were used as control verbs. We searched the corpus for the lemmas of the control verbs, paired with the word 'te' (*to*) within 20 words following the control verb. This would include the large majority of relevant sentences, since the word 'te' is obligatory in control constructions in Dutch. In the next step, only those sentences were included in which the relevant verb was indeed used as a control verb. Sentences in which the relevant verb was used with a different meaning than the intended one, as well as proverbs and passives, were excluded.

For the remaining sentences, it was scored whether the control verb was used as a subject- or object-control verb (some verbs can be used as subject and as object-control verbs in Dutch), and whether the sentence contained an explicit indirect object.

3.6.2 Results

Tables 3.6 and 3.7 show the results per verb for the subject- and object-control verbs, respectively. Three verbs ('waarschuwen' (*warn*), 'vragen' (*ask*), and 'bezweren' (*implore*)) can be used both as subject- and object-control verbs and thus they appear in both tables. In our ERP and fragment completion studies, they were included as subject-control verbs. One might question whether the verb 'helpen' (*help*) is technically a control verb. However, it can be used in the same construction as object-control verbs in Dutch, and was used in this way in our ERP and fragment completion studies.

Table 3.6 Results for the subject-control verbs: the total number of relevant subject-control sentences with this verb, the number and percentage of sentences with an indirect object (IO), without an indirect object (No IO) and the number of ambiguous sentences (?) are given.

Subject-control verb	**Total**	**No IO**	**IO**	**?**	**% no IO**	**% IO**
Zeggen (*say*)	116	113	1	0	97	1
Beloven (*promise*)	30	24	5	1	80	17
Verklaren (*declare*)	5	5	0	2	100	0
Vragen (*ask*)	4	1	3	0	25	75
Zweren (*swear*)	2	2	0	0	100	0
Verzekeren (*assure*)	1	0	1	0	0	100
Waarschuwen (*warn*)	1	1	0	0	100	0
Antwoorden (*answer*)	0	0	0	0	0	0
Bekennen (*confess*)	0	0	0	0	0	0
Berichten (*notify*)	0	0	0	0	0	0
Garanderen (*guarantee*)	0	0	0	0	0	0
Getuigen (*testify*)	0	0	0	0	0	0
Vertellen (*relate*)	0	0	0	0	0	0
Bezweren (*implore*)	0	0	0	0	0	0
Total	159	146	10	3	94	6

Table 3.6 shows that the subject-control verbs in the large majority of the cases did not take an indirect object (94%). Note, however, that this percentage is based on only half of the subject-control verbs (7), since the other half was not represented as subject-control verbs in the corpus. Furthermore, some of the verbs that were present in the corpus, were only represented by a small number of sentences. Most verbs that were represented in the corpus do show the general pattern, in that they more often do not take an indirect object. The only exceptions are the two verbs 'vragen' (*ask*) and 'verzekeren' (*assure*).

Table 3.7 shows that the verbs used as object-control verbs generally take an indirect object (81%). All the represented verbs show this pattern, except for 'waarschuwen' (*warn*), showing a 50/50 pattern.

We tested these patterns with a repeated measures MANOVA, using Indirect Object (present, absent) as a within item factor and Control (subject-control, object-control) as a between item factor, with the number of sentences as a dependent variable. This analysis showed no main effects for both Indirect Object and Control ($Fs < 1$), but a trend towards an interaction between these two variables ($F(1,16) = 3.94$, $p = .06$). Paired t-test showed no significant differences for the subject-control verbs ($t(6) = 1.24$, $p = .26$), nor for the object-control verbs ($t(10) = -1.56$, $p = .15$).

Table 3.7 Results for the object-control verbs: the total number of relevant object-control sentences with this verb, the number and percentage of sentences with an indirect object (IO) without IO and the number of ambiguous (?) sentences are given.

Object-control verb	Total	No IO	IO	?	% no IO	% IO
Vragen (*ask*)	145	18	127	0	12	88
Helpen (*help*)	49	16	33	0	33	67
Adviseren (*advise*)	27	10	16	1	38	62
Verplichten (*force*)	10	2	8	0	20	80
Bevelen (*command*)	10	1	9	0	10	90
Verzoeken (*request*)	6	1	5	0	17	83
Smeken (*beg*)	6	0	6	0	0	100
Verbieden (*prohibit*)	6	1	5	0	17	83
Waarschuwen (*warn*)	4	2	2	0	50	50
Bezweren (*implore*)	1	0	1	0	0	100
Gebieden (*order*)	1	0	1	0	0	100
Gelasten (*order*)	0	0	0	0	0	0
Ontraden (*discourage*)	0	0	0	0	0	0
Total	265	51	213	1	19	81

The verbs that can be used both as subject- and as object-control verbs seem to show inconsistent results. Moreover, because listeners can encounter these verbs in both types of control constructions, the frequency patterns cannot help them at the moment they encounter the verb. However, leaving these verbs out of the analysis led to the same pattern of results.

3.6.3 Discussion

In sum, the percentages show a different direction of effects for the subject- and object control sentences; in the majority of cases, subject-control verbs have an implicit indirect object and object-control verbs have an explicit indirect object. However, this difference was not significant, although we did find a trend towards a different ratio. We think that the number of sentences per verb in the corpus was too small to show significant differences. We thus have to be careful in interpreting these results.

If we look at the overall percentages, we see a clear dissociation between subject- and object-control verbs. Object-control verbs generally take an explicit indirect object (81%), whereas for subject-control verbs the indirect object is generally left implicit (94%). If listeners indeed pick up on this distribution and use it to make predictions about the sentence structure, this would mean the following for the sentences used in our earlier studies. After a subject-control verb (V1), listeners would not expect an indirect object. Therefore, NP2 would be interpreted as an object of a later verb. Thus, upon encountering V2, listeners will expect this verb to be transitive, so it can take NP2 as its argument. In contrast, after an object-control verb (V1), listeners would expect an explicit indirect object and NP2 will thus be interpreted as this indirect object. Upon encountering V2, listeners prefer this verb to be intransitive, because there is no free NP in the sentence that can serve as its object.

This pattern of results corresponds nicely to the results found for the subject-control sentences in Chapter 2 and the present chapter. Both in the on- and off-line experiments, we found a reliable preference for transitive V2s, which is in agreement with the frequency patterns that listeners hear in the input.

For the object-control items, the results of this corpus study are in line only with the off-line fragment completion test, showing a preference for intransitive completions for object-control items. However, the present results stand in contrast with the on-line ERP results, which sometimes showed a transitive preference and sometimes no preference. Thus, the frequencies in the input correlate much better with off-line judgments about sentences (as in a fragment completion test) than with on-line interpretations of sentences.

One has to bear in mind that these relations are indeed correlations between the patterns of results. Thus, they do not say anything about the directionality or causality of the effects. One potential explanation for these results is that frequencies in the input over time lead listeners to prefer a certain parsing of the sentence. Alternatively (or additionally), a third underlying factor can be responsible for both the frequencies in the input and the preference for a certain parse of the sentence. One such factor could relate to the double role of the indirect object in object-control sentences. In object-control sentences, the indirect object of the object-control verb always plays an important additional role, namely as the understood subject of the second verb in the sentence. Thus, speakers might less easily leave the indirect object implicit since then the understood subject of the second verb will also remain implicit. At the same time, in off-line fragment completion, it is much easier to come up with a verb of which the understood subject is already present in the sentence.

In conclusion, we have to be careful in interpreting the results of this corpus study, since some control verbs were very infrequent or not present at all in the corpus. Still, the descriptive results are compatible with the reliable preference found in our ERP and off-line studies for transitive verbs after subject-control verbs. For object-control verbs, the results are in line with the preference found in our earlier fragment completion studies, but not with the preference found in the ERP studies.

Chapter 4

Pitch accents in context:

How listeners process accentuation in referential communication

Abstract

We investigated whether listeners are sensitive to (mis)matching accentuation patterns with respect to contrasts in the linguistic and visual context, using Event-Related Potentials. We presented participants with displays of two pictures followed by a spoken reference to one of these pictures (e.g., *the red ball*). The referent was contrastive with respect to the linguistic context (utterance in the previous trial: e.g., *the blue ball*) or with respect to the visual context (other picture in the display; e.g., a display with a red ball and a blue ball). The spoken reference contained a pitch accent on the noun (*the red BALL*) or on the adjective (*the RED ball*), or an intermediate ('neutral') accentuation. For the linguistic context, we found evidence for the Missing Accent Hypothesis: Listeners showed processing difficulties, in the form of negativities in the ERPs, for missing accents, but not for superfluous accents. 'Neutral' or intermediate accents were interpreted as 'missing' accents when they occurred late in the referential utterance, but not when they occurred early. For the visual context, the results suggest that mentioning of a redundant color adjective (e.g., in the case of a display with a red ball and a red hat) leads to processing problems, especially when the adjective does not contain a pitch accent. Furthermore, our data show some evidence for the Missing Accent Hypothesis in the visual context as well.

This chapter is largely identical to an article that is currently under revision at Neuropsychologia as: Bögels, S., Schriefers, H., Vonk, W., & Chwilla, D. J. (under revision). Pitch accents in context: How listeners process accentuation in referential communication.

When a speaker intends to direct the listener's attention to a certain entity, for example, a red Porsche, he or she can choose from different utterances (*the Porsche*, *the red car*, *the sports car*, etc.). The speaker's eventual choice in such a referential communication situation will, among other factors, depend on the context in which the reference is made. Two kinds of context can be distinguished. First, as a speaker, you need to know which other objects are visually present in the environment, because you need to distinguish your intended referent from these other objects. In the following, we will refer to this as the visual context. For example, when you are riding on a busy highway and want to refer to the Porsche in our example, it will probably not suffice to say: *Look at the car!* You will have to be more specific, and, for example, say: *Look at the Porsche!* or *Look at the red car!*, depending on whether there are cars with other colors and/or of other brands on the highway as well. Another kind of context is the discourse context, or the conversation you are engaged in. We will refer to this as the linguistic context. If your conversational partner just talked about a beautiful black Porsche, it is possible for you to say: *Yes, but look at this red Porsche* or *Yes, but look at this red one* (you can leave out part of the reference, because it was just mentioned in the linguistic context).

Thus, both the visual and the linguistic context can affect the choice of a referential utterance. However, speakers often provide more information than is necessary, that is, they overspecify (e.g., Maes, Arts, & Noordman, 2004; Pechmann, 1984). Then, it might still be useful to indicate which information is most important to identify the referent. This information is often the property of the object that is contrastive with respect to the visual or linguistic context. This contrastive information can be marked prosodically, by a pitch accent. In the visual context, if a black and a red Porsche are overtaking each other in front of you, you could say: *look at the RED Porsche* (pitch accents are indicated by capitalizing the accented word). In the linguistic context, if your conversational partner just talked about a black Porsche, you could also say *Yes, but look at this RED Porsche!* A pitch accent can thus indicate which part of the utterance (and thus which aspect of the object) is contrastive with respect to other referents visually present, or mentioned earlier in the discourse.

If this prosodic marking of contrastive information is useful for listeners, one would expect that they are sensitive to these markings. In the present paper, the role of accentuation in the comprehension of referential noun phrases (NPs) with respect to both the visual and the linguistic context is investigated (in section 4.6 we also report a small study on the production of accentuation in the visual context). Referential communication can be studied in several ways, via intuition, observation, and experimentation (Clark & Bangerter, 2004). As these authors point out, each of these approaches has its own merits and limitations. In the present paper, we use carefully controlled experimentation as our method. In the following, we give an overview of experimental studies on processing of accentuation in the visual context and in the linguistic context.

Most previous research on processing of pitch accents has focused on the linguistic context. The general view is that pitch accents mark new or contrastive information in an utterance, that is, information that is new with respect to the preceding linguistic context. Studies using eye-tracking have shown that the comprehension of references to visual objects is facilitated when new information is accented and given information is deaccented (e.g., Dahan et al., 2002; Ito & Speer, 2008; Weber et al., 2006). Also, a number of ERP studies have focused on the comprehension of sentences in a linguistic context, creating a contrastive focus on a single word. For example, Magne et al. (2005) looked at question answer pairs (in French) such as (1) and (2).

1. Did he give a ring or a bracelet to his wife?
2. a. He gave a RING to his wife.
   b. He gave a ring to his WIFE.

In the answer to question (1), the contrastive focus should be on *ring* (as contrasted with *bracelet*). In the answer (2a) the accent on *ring* and the absence of one on *wife* thus fit the focus introduced by the question. In contrast, in (2b) *ring* is focused but not accented (i.e., has a 'missing accent'), whereas *wife* is not focused but accented (i.e., has a 'superfluous accent'). Magne et al. found processing difficulties for the mismatching answers (such as 2b) at the positions of missing and superfluous accents. The exact ERP signature depended on the position of the word in the sentence. Sentence medial mismatching words elicited a P300 effect, whereas sentence final mismatching words yielded an N400 effect, which the authors related to sentence-final integration processes. Other ERP experiments (Hruska & Alter, 2004; Hruska et al., 2001; Johnson et al., 2003; Toepel et al., 2007) also elicited a certain focus structure by a linguistic context, which was or was not matched by the accentuation pattern of the target sentence. All of these studies showed some processing difficulty when the focus structure did not match the accentuation of the sentence, but the actual ERP signature differed. Hruska et al. (2001) found an N400 effect for a missing accent on a sentence medial noun and a positivity for a missing accent on a clause final verb. Interestingly, no processing difficulties were found for superfluous accents (although pitch accents matching the focus structure yielded an 'expectancy negativity'). In a similar vein, other studies also found processing difficulties only for missing, but not for superfluous accents. In Johnson et al. (2003), this difficulty was reflected by a frontal negativity around 400 msec, in Hruska and Alter (2004) as an N400 effect, and in Toepel et al. (2007) as a centro-posterior negativity. In sum, both the polarity and the scalp distribution of these ERP effects appear to be variable. Moreover, the studies differ in what kinds of prosodic mismatch lead to processing problems. All the above studies found processing difficulties for a deaccented element which should be in focus, relative to the previous utterance (i.e., for missing accents). However, only some of the studies also found difficulties for accented elements that were not in focus (i.e., for superfluous accents). All ERP studies mentioned until now investigated sentence processing. However, an fMRI study by Van Leeuwen et al. (2007) looked at accentuation in the comprehension of referential NPs. A mismatch between focus and accent led to an increase in activation in the posterior and anterior LIFG, areas that are involved in phonological and semantic processing.

As compared to effects of the linguistic context, only little on-line research has addressed the relation between accentuation and visual context during the comprehension of utterances. An eye-tracking study by Eberhard et al. (1995) showed that listeners use accentuation patterns on-line, to constrain the set of visually presented referents. When presented with the utterance *Touch the LARGE blue square*. upon hearing the accented word *LARGE*, listeners immediately looked more to large targets (large blue square) with a small competitor (small blue square) than to large targets without such a competitor. As far as we know, no ERP studies have addressed the question how listeners process pitch accents in a visual context.

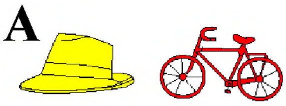
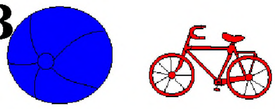
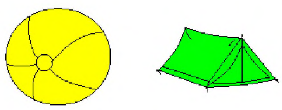
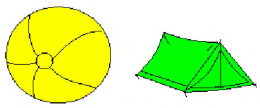
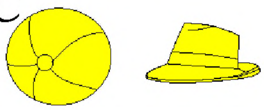
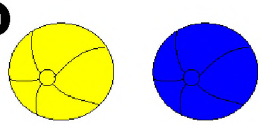
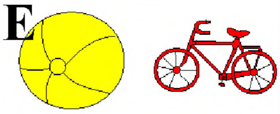
In the present experiment, we investigated both the effect of accents marking a contrast with the (preceding) linguistic context, and the effect of accents marking a contrast with the (simultaneous) visual context, using the same dependent measure (ERPs) and the same experimental setting. The main question is how listeners process accents in these two contexts. We used simple displays with two potential referents. These referents varied in object and color. Each display was followed by an auditorily presented NP (determiner, color adjective, and noun), referring to one of the objects in the display. In both the linguistic and the visual context, either the color or the object could be the contrastive information. In the linguistic context, the object was contrastive when the adjective was repeated relative to the previous NP (*the yellow hat* followed by *the yellow ball*; see Table 4.1, condition A), while the color was contrastive when the noun was repeated (*the blue ball* followed by *the yellow ball*; see Table 4.1, condition B). In the visual context, the object was contrastive when two different objects with the same color were presented in the current display (a yellow ball and a yellow hat; see Table 4.1, condition C), while the color was contrastive when two exemplars of the same object were presented with different colors (a blue ball and a yellow ball; see Table 4.1, condition D). The referential NPs that followed the visual displays were realized with three different accentuation patterns, an accent on the adjective (*the YELLOW ball*), an accent on the noun (*the yellow BALL*), or a 'neutral' accentuation, leading to a mismatching, a matching, and a neutral accentuation pattern, relative to the context, in conditions A to D (see Table 4.1, for details see Materials).

The NPs with a neutral accentuation provide a condition that, with respect to prosodic-acoustic aspects, falls in between the conditions with an accent on the noun and an accent on the adjective (see Materials). We refrain from specific hypotheses about this neutral accent condition. It might be the case that this accentuation pattern is truly 'neutral', such that it fits any contrast relative to the (linguistic or visual) context. Alternatively, it might exclusively match a referent that is in every respect different from both the visual and the linguistic context. Therefore, we also added a condition with visual display containing such a referent, coupled with a neutrally accented NP (Table 4.1, condition E).

Unlike most previous ERP studies, we chose not to focus the participants' attention to the critical prosodic information with a (prosodic) acceptability judgment task. Instead, we asked participants to identify the referent of the NP, as they would do in a natural referential communication situation.

For the accentuation conditions with a pitch accent on the adjective or on the noun in the linguistic context, two types of mismatching accents can be distinguished. First, the adjective or the noun can be contrastive with respect to the context, but not accented; we will refer to this situation as a *missing accent*. Alternatively, the adjective or the noun is not contrastive, but is nevertheless accented; we will refer to this situation as a *superfluous accent*. Note that, parallel to the studies described above, all mismatching accentuation patterns in the present study contain both a missing and a superfluous accent. When the object is the contrastive information (see Table 4.1, condition A), a mismatching accentuation (e.g., *the YELLOW ball*) implies a superfluous accent on the adjective and a missing accent on the noun (compare the corresponding matching accentuation *the yellow BALL*). In the color contrastive condition (Table 4.1, condition B), a mismatching accentuation (e.g., *the yellow BALL*) implies a missing accent on the adjective and a superfluous accent on the noun (compare the corresponding matching accentuation *the YELLOW ball*). As described above, some studies found processing difficulties for both missing and superfluous accents (e.g., Magne et al., 2005) and others only for missing accents (e.g., Hruska & Alter, 2004). On the basis of these findings, two competing hypotheses can be derived, which we will hereafter refer to as the Missing Accent Hypothesis and the Wrong Accent Hypothesis.

Table 4.1 The experimental design, consisting of the subdesigns linguistic context and visual context, and one baseline condition. NPs in bold are matching relative to the context, NPs preceded by an asterisk are mismatching relative to the context.

		Object-contrastive	**Color-contrastive**	**Both-contrastive**
Linguistic context	N-1	**A** 	**B** 	
		De gele hoed “The yellow hat”	De blauwe bal “The blue ball”	
	N			
	Adjective-accent	*De GELE bal “The YELLOW ball”	**De GELE bal** “The YELLOW ball”	
	Noun-accent	**De gele BAL** “The yellow BALL”	*De gele BAL “The yellow BALL”	
	Neutral-accent	De gele bal “The yellow ball”	De gele bal “The yellow ball”	
Visual context		**C** 	**D** 	
	Adjective-accent	*De GELE bal “The YELLOW ball”	**De GELE bal** “The YELLOW ball”	
	Noun-accent	**De gele BAL** “The yellow BALL”	*De gele BAL “The yellow BALL”	
	Neutral-accent	De gele bal “The yellow ball”	De gele bal “The yellow ball”	
Baseline				**E** 
	Neutral-accent			**De gele bal** “The yellow ball”

In the following, we will assume that listeners can detect a missing and/or superfluous accent right on perceiving the word with the mismatching accent. This assumption is supported by the ERP studies described above, which all show ERP effects to missing and/or superfluous accents right on the word with the missing accent. According to the Missing Accent Hypothesis, only missing accents, and not superfluous ones, lead to processing difficulties. In the present study, ERP effects in the color contrastive condition (Table 4.1, condition B) should start right on the unaccented adjective (*the yellow BALL* versus *the YELLOW ball*), that is, before onset of the noun. For the object contrastive condition (Table 4.1, condition A), by contrast, no effect should be obtained on hearing the adjective since the mismatching accentuation (*the YELLOW ball*) has a superfluous accent on the adjective. Rather, as the missing accent concerns the noun, an effect of the mismatching accentuation (*the YELLOW ball*) relative to the matching accentuation condition (*the yellow BALL*) should start later, when hearing the noun. The Wrong Accent Hypothesis predicts that the listener reacts to both missing and superfluous accents. As the mismatching NPs in both the color contrastive and the object contrastive condition have a wrong accentuation on the adjective (a missing accent in the color contrastive condition and a superfluous accent in the object contrastive condition), ERP effects should start to show up on the adjective in both cases.

If ERP effects to missing and/or superfluous accents continue throughout the whole NP once they are triggered, onset differences are the main differential predictions of the two hypotheses. Specifically, in the object contrastive condition (Table 4.1, condition A), according to the Wrong Accent Hypothesis the ERP effects should start already on hearing the (accented) adjective. In contrast, the Missing Accent Hypothesis predicts that effects will only start on hearing the (unaccented) noun. However, if the ERP effects are restricted to only those parts of the NPs containing a mismatching accent, there is an additional differential prediction between the two hypotheses. In that case, in the color contrastive condition (Table 4.1, condition B), the Missing Accent Hypothesis predicts only an effect on the (unaccented) adjective and no effect on the (accented) noun, whereas the Wrong Accent Hypothesis predicts ERP effects on both the adjective and the noun. Given the variability of ERP signatures for mismatching accents in the literature, we do not specify the hypotheses in terms of specific ERP components.

If listeners process matching and mismatching accentuation patterns with respect to the visual context in a similar way as with respect to the linguistic context, the Missing and Wrong Accent Hypotheses will also apply to the visual context (see the matching and mismatching accentuations in Table 4.1, conditions C and D).

4.1 Methods

4.1.1 Participants

Thirty-two right-handed native speakers of Dutch participated in the Experiment. They had no visual or hearing problems. They were all students at the Radboud University Nijmegen and received 10 euros per hour or course credit for their participation. Seven participants were excluded from the analysis because of excessive artifacts and one because she fell ill during the experiment. The remaining 24 participants (4 men, 20 women) had a mean age of 21.9 years (range 18 to 26).

4.1.2 Materials

Visual materials. Seventy-two pictures of inanimate objects were selected from the picture gallery available at the Max Planck Institute for Psycholinguistics, Nijmegen. All objects had monosyllabic names of common gender (used with the definite determiner 'de' in Dutch). The depicted objects had no natural or preferred color. Of these 72 objects, 48 were used as experimental objects, and the remaining 24 objects were used in filler trials. The size of the pictures was scaled such that they all fit in an imaginary square of 144 by 144 pixels. Four different colors were used in the experimental trials: red (RGB: 255 0 0), blue (0 0 255), green (0 255 0), and yellow (255 255 0). The colors pink (255 105 180), purple (148 0 211), grey (169 169 169), and brown (139 69 19) were used in the filler trials. The names of these colors in Dutch all consist of one stressed syllable followed by a schwa (e.g., *gele*) when followed by a common gender noun. The use of different colors in the filler trials allowed us to avoid repetition of colors from trial to trial in situations other than the linguistic context items (see Design). The pictures were combined in two-picture displays by forming groups of four pictures each that always occurred together in different configurations. Such a group never contained pictures with the same onset phoneme or of the same semantic category.

Auditory materials. A female native speaker of Dutch recorded the auditory materials. She produced NPs for all colored objects, consisting of a determiner, a color adjective, and a noun. The NPs for experimental trials were produced in three different ways: with a pitch accent on the adjective, with a pitch accent on the noun, and with a 'neutral' accentuation. The auditory materials for the fillers were produced with only a neutral accentuation.

For recording of the NPs with a neutral accentuation, the speaker was presented with written NPs on a computer screen, one by one, and instructed to read them out loud with a neutral intonation. In these recordings, an NP was never preceded by an NP with the same adjective or the same noun.

For recording of the NPs with an accent on the adjective or the noun, we used a linguistic context. Pilot recordings using both a linguistic and a visual context showed that the linguistic context more easily elicited the intended accentuation than the visual context (in line with a production study by Pechmann, 1984 and the production study reported in section 4.6). Both accents on the adjective and accents on the noun were elicited in the same session and in a random order. The speaker was first presented with a written NP which had to be produced with a neutral accentuation. Then, while the first NP stayed on the screen, an experimental NP appeared underneath it. If the experimental NP contained the same color adjective as the first NP, the speaker realized the experimental NP with a pitch accent on the noun. If the experimental NP contained the same noun, a pitch accent was realized on the adjective.

The three accentuation patterns clearly differed in the ToDI transcriptions (Gussenhoven, 2004; see Table 4.2) and in the acoustic analyses of the auditory materials (see Table 4.3). The acoustic analyses showed that the NPs with an accent on the noun and an accent on the adjective differed on all measures of adjective and noun, but most prominently on the pitch range measure. The NPs with a neutral accentuation also differed from the other types of NPs on the pitch range measure.

Table 4.2 ToDI transcriptions for the three accent conditions.

NP (Dutch)	De	gele	bal	
English translation	"The	yellow	ball"	
Adjective-accent	%L	H*L	-	L%
Noun-accent	%L	-	H*L	L%
Neutral-accent	%L	H*L	!H*L	L%

Table 4.3 Length, loudness, and pitch range of the adjective and the noun in the three accent conditions.

	Adjective-accent	**Noun-accent**	**Neutral-accent**
Adjective length (in msec)	352 (35)*	339 (36)	342 (35)
Adjective loudness (in dB)	69.9 (1.6)	67.2 (1.7)*	69.8 (1.4)
Adjective pitch range (in Hz)	65.7 (11.8)*	26.6 (14.3)*	47.6 (17.5)*
Noun length (in msec)	514 (77)*	542 (75)	553 (77)
Noun loudness (in dB)	58.5 (2.2)*	64.9 (2.3)*	62.0 (2.1)*
Noun pitch range (in Hz)	18.55 (8.1)*	62.2 (16.5)*	39.5 (18.9)*

* This value differs significantly from all other values in the same row.

Items. In the experiment, a two-picture display was always followed by an auditory NP, referring to one of the pictures in the display. In the following, this combination of display and an auditory NP will be referred to as a trial. The picture indicated by the referential NP will be referred to as the target picture. For each condition, this target picture occurred at the left position in one half of the trials and at the right position in the other half. In the linguistic context, an experimental item comprised two trials: a context trial which sets up the linguistic context, and a target trial. In the visual context, an experimental item consisted of only a target trial as the visual context is set up within one visual two-picture display. The baseline items (Table 4.1, condition E) and the filler items always consisted of a single trial.

4.1.3 Procedure

Participants read an instruction that informed them about the course of the experiment. A trial started with a fixation cross in the middle of the screen. Participants were instructed to look at the fixation cross and not to make eye movements for as long as it was presented on the screen. After 1000 msec, a frame appeared around the fixation cross (width: 400 pixels, height: 200 pixels). Within this frame, two pictures were presented such that the midpoint of the imaginary square (144 by 144 pixels) was placed 120 pixels to the right and to the left of the fixation cross. This distance was close enough for participants to see both pictures while looking at the fixation cross. After 1500 msec, the two pictures and the frame disappeared, and, 500 msec later, participants heard an NP through headphones, referring to one of the pictures. In 20% of the trials, a question mark appeared 1000 msec after offset of the auditory NP, upon which participants had to indicate which object the NP referred to with a left or right button press. Participants had to prepare for the task on every trial, since they could not predict after which trials the question mark would appear. The question mark never appeared after the context trial of a linguistic context item. Participants were instructed to keep their left and right index fingers loosely on the left and right buttons. At the end of each trial (1000 msec after the NP or 150 msec after the button press), the fixation cross or question mark disappeared and a small picture of an eye was presented for 2000 msec, indicating that participants could blink their eyes.

The experiment was divided into two sessions on different days. In each session, visual context items and linguistic context items were presented in separate parts of the experiment. Participants received a training block of 12 linguistic context items and 12 filler items (36 trials) before the linguistic context parts and a training block of 18 visual context items and 14 filler items (32 trials) before the visual context parts. These training blocks comprised the same conditions as the experimental blocks, but contained different color-object combinations. The experimental blocks each took 10-15 minutes to complete. Participants took a short break in between these blocks and a longer break in between the two parts of each session.

4.1.4 Design

Factors. The experiment consisted of two separate subdesigns, one for the linguistic context and one for the visual context. The linguistic context subdesign had two crossed factors. The first was Contrast with the levels color-contrastive and object-contrastive, relative to the linguistic context, that is, the previous trial. In the color-contrastive condition, the referential NPs in the previous context trial contained the same noun (object) as the NP in the target trial, but with a different color adjective. In the object-contrastive condition, the NP in the previous context trial contained the same color adjective as the NP in the target trial, but a different noun (object). The second factor was Accent, referring to the auditory NP, with the levels noun-accent (pitch accent on the noun), adjective-accent (pitch accent on the adjective), and neutral-accent (neutral accentuation). Crossing these two factors resulted, for both types of Contrast (object-contrastive and color-contrastive), in one condition with a mismatch between the contrastive information and the accented element, one condition with a match, and one neutral condition (see Table 4.1, conditions A and B).

The visual context subdesign had the same two crossed factors as the linguistic context subdesign. The factor Contrast also had the levels color-contrastive and object-contrastive, in this case in the visual context. In the color-contrastive condition, the context picture displayed the same object in a different color as the target picture. In the object-contrastive condition, the context picture had the same color as the target picture but displayed a different object. This factor was crossed with the factor Accent (with the levels noun-accent, adjective-accent, and neutral-accent), again resulting, for both contrast conditions, in one condition with a mismatch between the contrastive information and the accentuation pattern, one with a match, and one neutral condition (see Table 4.1, conditions C and D).

One additional experimental condition was used in which both the visual and the linguistic context were neutral, in the sense that both the color and the object of the current target picture were different from those of the previous target picture and those of the current context picture. This display (both-contrastive) was always coupled with a neutrally accented

NP, serving as a baseline for the neutral-accent conditions (see Table 4.1, condition E). All filler items had a neutral context and a neutral accent.

Comparisons. The fully crossed Contrast (2) by Accent (3) design lends itself to different potential comparisons between conditions. One could compare the same acoustic tokens in different linguistic or visual contexts. This corresponds to comparisons within the rows of Table 4.1 (e.g., *the YELLOW ball* in a color-contrastive situation, condition A, and the same acoustic token in an object-contrastive situation, condition B). However, these comparisons might lead to potential artifacts in the ERPs.

For the linguistic context, the critical NP in the object-contrastive condition contains a repetition of the color adjective relative to the previous NP, and the critical NP in the color-contrastive condition contains a repetition of the object noun. This difference is inherent to the linguistic context since a referential NP can only be purely color contrastive when the noun (object) is repeated, and purely object contrastive when the color adjective is repeated. However, language-relevant ERP components such as the N400 show a reduction in response to the repetition of a word (e.g., Rugg & Nagy, 1987; Swick & Knight, 1997; Schnyer, Allen, & Forster, 1997). This implies that an N400 on the adjective might be reduced for the object-contrastive condition, and an N400 on the noun might be reduced for the color-contrastive condition. To check whether this was indeed the case in our data, we compared the same Accent conditions in the different linguistic contexts (conditions A versus B in Table 4.1). We found a reduction of the N400 around 300-500 msec after onset of the noun for conditions with noun repetition (color-contrastive: Table 4.1, condition B) relative to conditions without it (conditions A and E). See section 4.4 for results of statistical analyses and discussion.

For the visual context subdesign, the comparison of identical acoustic tokens is also problematic, but for a different reason. In the object-contrastive condition (Table 4.1, condition C), mentioning the color adjective is redundant, because both objects have the same color. Logically, just mentioning the object suffices. Thus, participants can only decide which object the NP refers to on hearing the noun. Therefore, the pictures have to be retained in working memory for a longer time than in the color-contrastive condition (D), where participants can decide which object the NP refers to after only having heard the color adjective. This situation might lead to confounds in the ERP effects (e.g., King & Kutas, 1995). In our data, we found more negative-going ERPs for the conditions with two objects of the same color (Table 4.1, condition C), relative to the conditions with two objects of different colors (conditions D and E). See section 4.5 for results of statistical analyses and discussion of this effect.

Given these considerations and the corresponding results, we decided to compare different accentuation conditions *within* the same contrastive context. In terms of Table 4.1, we thus compared the different Accent conditions within each Contrast condition (A, B, C, or D). For these comparisons, low level acoustic differences between the accentuation conditions might lead to differences in the ERPs. However, in earlier ERP research on accentuation, no differences were found between accented and unaccented words per se (e.g., Magne et al., 2005). Moreover, we can look at potential interactions between the factors Contrast and Accent, which cannot be due to acoustic differences.

Order of presentation. The two subdesigns appeared in separate parts of the experiment. The linguistic context part consisted of 32 items per condition. Each item consisted of a context trial and an experimental trial. This yielded 192 items (384 trials) in total. To these, 192 filler items (consisting of 1 trial) were added. The resulting 576 trials were subdivided into 8 blocks of 72 trials each. A block had 4 experimental items in each of the 6 conditions and 24 filler items. Not more than two experimental items (pairs of context trial and experimental trial) or two filler items appeared in a row.

The visual context part consisted of 32 items (consisting of a single trial) for each of the 6 conditions (192 experimental items in total) and 144 filler items. These 336 items were subdivided into 4 blocks of 84 items each, consisting of 8 items in each of the 6 conditions and 36 filler items. At the end of each of these 4 blocks, 8 experimental items of the baseline condition (consisting of a single trial; see Table 4.1, condition E) and 6 filler items were added. Not more than two experimental items or one filler item appeared in a row in the visual context blocks.

For all blocks, a quasi-random order was created, under the following restrictions. Apart from the context and target trials constituting a linguistic context item, two trials with the same color and/or the same object in the display never appeared in direct succession. At least three trials separated two trials with the same object and at least one trial separated two trials with the same color. Three different experimental lists were created. In each list, the same acoustic token of an NP occurred twice, but in a different Contrast condition. These two tokens occurred in different sessions. The same order of visual displays was used in the three experimental lists, but the three differently accented tokens were rotated over the three lists. In each session, the participants were presented with four linguistic context blocks and two visual context plus baseline blocks. Half of the participants first saw the four linguistic context blocks and the other half first saw the two visual context blocks. This order remained constant across the two sessions.

4.1.5 Apparatus

EEG was recorded from 25 tin electrodes. Electrode positions were a subset of the international 10-20 system, consisting of three midline electrodes (Fz, Cz, and Pz) and 22 lateral electrodes (AF7/8, F7/8, F3/4, FC3/4, FT7/8, T7/8, C3/4, CP5/6, P7/8, P3/4, and PO7/8). This montage has been used in earlier auditory ERP studies (e.g., Chapter 2: Bögels et al., 2010 and Chapter 3: Bögels, Schriefers, Vonk, & Chwilla, in press). During the recording, the left-mastoid served as reference. The signals were re-referenced to the average of both mastoids before the analysis. Vertical EOG electrodes above and below the right eye and horizontal EOG electrodes at the outer canthi were used to monitor eye blinks and eye movements. Impedance was kept below 3 kΩ for the EEG and EOG electrodes. Signals were amplified with a time constant of 8 seconds and a bandpass filter of .02 to 100 Hz and digitized with a 16-bit A/D converter at a sampling frequency of 500 Hz.

4.1.6 Data-analysis

The raw EEG data were filtered with a low pass filter of 30 Hz. Then, averages were computed for epochs of 150 msec before until 1500 msec after onset of the referential NP of the target trial, for all conditions. The first 150 msec of this epoch served as a baseline. We extended the epoch to 1500 msec after NP onset, because this included at least the complete NP for all experimental trials and never extended into the period were participants performed the task or blinked their eyes. We time locked the ERPs to NP onset, because other time-locking points could lead to differences in the baselines for different conditions. Time-locking to NP onset is unproblematic, because the jitter between experimental NPs in adjective and noun onset was small. The adjective started on average 68 msec (range 28 to 133 msec, SD = 16 msec) after NP onset and the noun started on average 412 msec (range 343 to 504 msec, SD = 30 msec) after NP onset. We excluded all epochs that contained excessive EEG (>100 μV) or EOG (> 75 μV) amplitude. For the different conditions, a mean of 29 to 30 items (of a maximum of 32 items, SDs between .39 and .61) entered the eventual analyses. The number of removed items did not differ significantly between conditions (Fs < 1).

Since we had no hypotheses for specific ERP effects, we first performed exploratory time course analyses for 30 consecutive 50 msec windows between 0 and 1500 msec. On the basis of significant effects in at least two consecutive time windows in combination with visual inspection of the grand average waveforms, we decided which time windows of at least 100 msec to use in the analyses.

For both the linguistic and the visual context designs, we first only included the adjective-accent and noun-accent conditions in the analyses, using the critical factors Contrast (color-contrastive, object-contrastive) and Accent (noun-accent, adjective-accent). Main effects of Contrast are not reported because these could be due to word repetition and redundancy of the color adjective (see Design and Appendices A and B). Afterwards, we performed separate analyses for the neutral-accent condition together with the noun-accent and together with the adjective-accent condition.

For both the linguistic and visual context design, we performed multivariate repeated-measures analyses (e.g., Vasey & Thayer, 1987) for the midline and lateral electrodes. Next to the critical factors Contrast and Accent, the midline analysis included the factor Electrode (Fz, Cz, Pz), and the lateral analysis included the factors Hemisphere (left, right), Region of Interest (ROI: anterior, posterior), and Electrode. Crossing of the factors Hemisphere and ROI led to four quadrants with four electrodes each: left anterior (AF7, F7, F3, FC3), right anterior (AF8, F7, F4, FC4), left posterior (CP5, P3, P7, PO7), and right posterior (CP6, P4, P8, PO8). Three additional electrodes on each hemisphere (FT7, T7, C3, FT8, T8, C4) were excluded from these analyses, to have an equal number of electrodes in each quadrant. If the distribution of an effect could not be shown via analyses of the separate ROIs and interactions including the factor Electrode were found, separate analyses for all single electrodes were performed. We only report effects including the critical factors. For the figures only, not for the statistical analyses, the grand average waveforms were smoothed off-line using a 5 Hz lowpass filter.

4.2 Results

4.2.1 Behavioral results

The results of the referent identification task after 20% of the trials showed that participants did not have any problems identifying the correct referent for the utterance. On average, participants made 1 error (out of 194 trials, SD = 1.47, range between 0 and 5 errors). The average reaction time measured from onset of the question mark was 568 msec (SD = 119 msec, range between 388 and 831 msec).

4.2.2 ERPs for linguistic context

Effects of noun-accent and adjective-accent conditions. Grand average waveforms for the different Accent conditions (adjective-accent, noun-accent, and neutral-accent) together are shown in Figure 4.1 for the color-contrastive condition and in Figure 4.2 for the object-contrastive condition. Focusing on the adjective-accent (black solid line) and noun-accent (black dashed line) conditions, Figure 4.1 suggests an early effect, before 400 msec (see frontocentral electrodes at the midline and the left hemisphere), with more negative-going ERPs for the noun-accent (mismatching) than the adjective-accent (matching) condition. In contrast, Figure 4.2 suggests the presence of a later effect, after 400 msec (see centroparietal electrodes), with more negative-going ERPs for the adjective-accent (mismatching) than the noun-accent (matching) condition. Note that these effects are in opposite directions. Based on the time course analyses, the early effect was quantified in a 300-400 msec window and the late effect in a 450-550 msec window. In Figures 1 and 2, visual inspection also suggests differences between the conditions after 1000 msec. However, analyses showed that these effects were unreliable or inconsistent. Therefore, these late effects are not reported.

Mean amplitudes in the early (300-400 msec) and late (450-550 msec) windows were entered in one analysis including the critical factors Window (early, late), Accent, and Contrast. The midline analysis yielded a Window by Accent by Contrast by Electrode interaction ($F(2,22) = 3.53$, $p < .05$) and the lateral analysis showed a trend towards a Window by Accent by Contrast by Hemisphere by ROI interaction ($F(1,23) = 3.79$, $p = .06$). Therefore, we analyzed both time windows separately.

For the early window (300-400 msec), we found an Accent by Electrode interaction ($F(2,22) = 4.38$, $p < .05$) in the midline analysis and trends towards an Accent by ROI ($F(1,23) = 4.25$, $p = .05$) and an Accent by Contrast by Electrode interaction ($F(3,21) = 2.44$, $p = .09$) in the lateral analysis. Follow-up analyses were performed for the two contrast conditions. In the color-contrastive condition (Figure 4.1), the midline analysis showed a trend towards a main effect of Accent ($F(1,23) = 3.88$, $p = .06$) and an interaction between Accent and Electrode ($F(2,22) = 5.36$, $p < .05$). The lateral analysis yielded interactions between Accent and ROI ($F(1,23) = 11.06$, $p < .01$) and between Accent and Electrode ($F(3,21) = 5.12$, $p < .01$). Follow-up analyses showed that the early, negative-going effect for the noun-accent (mismatching) condition relative to the adjective-accent (matching) condition was distributed over the anterior electrodes and more pronounced over the left hemisphere (ps < .05 for AF7, F3, FT7, FC3, C3, Fz, Cz, and F4). In the object-contrastive condition (Figure 4.2), no differences were found between the noun-accent and adjective-accent conditions for the early window (Fs < 1).

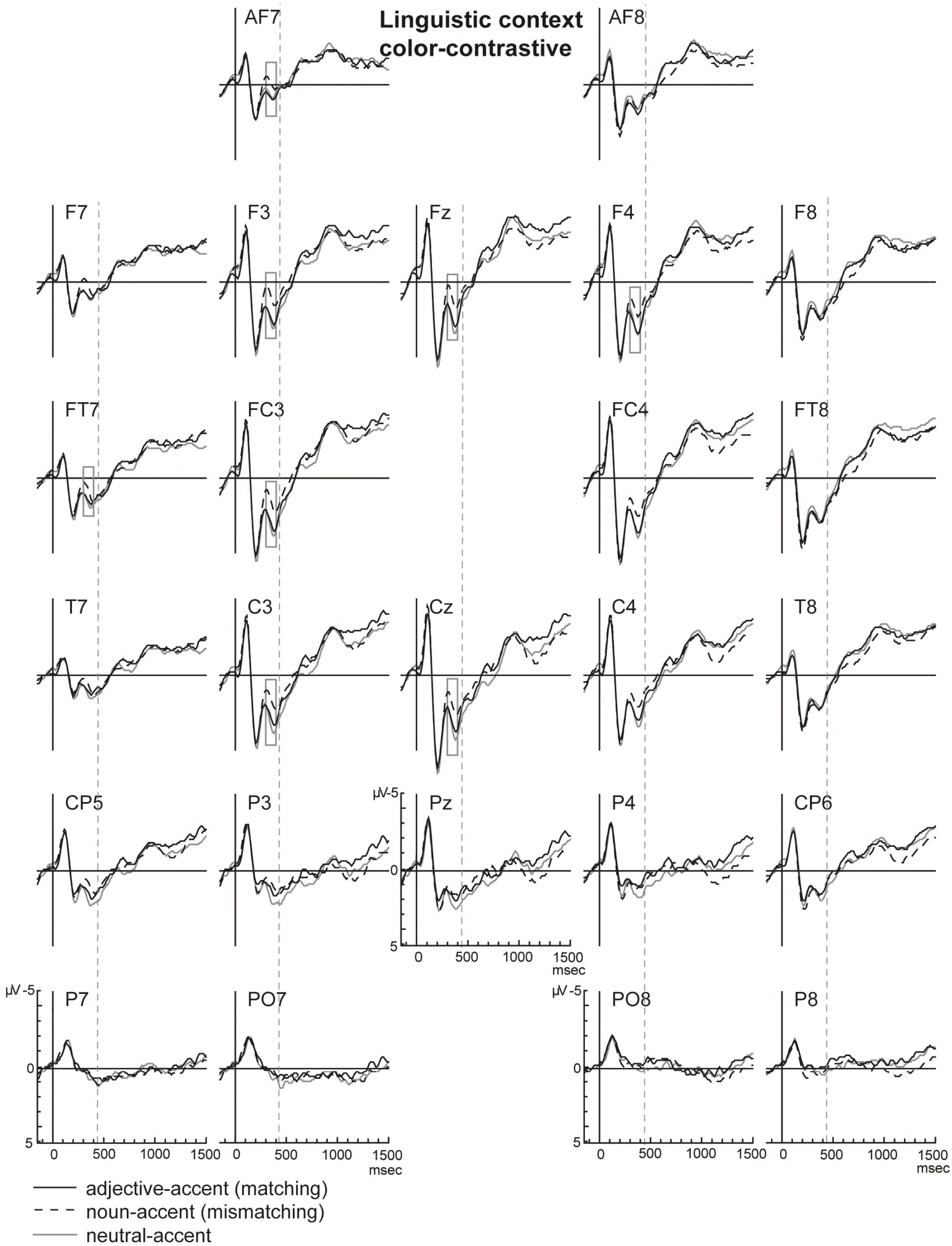


Figure 4.1 Grand average waveforms for all electrodes for the three Accent conditions (adjective-accent, noun-accent, neutral-accent) in the color-contrastive condition in the linguistic context. Dotted vertical lines indicate the average onset of the noun (412 msec). Boxes indicate time windows with significant differences between the adjective-accent and noun-accent conditions.

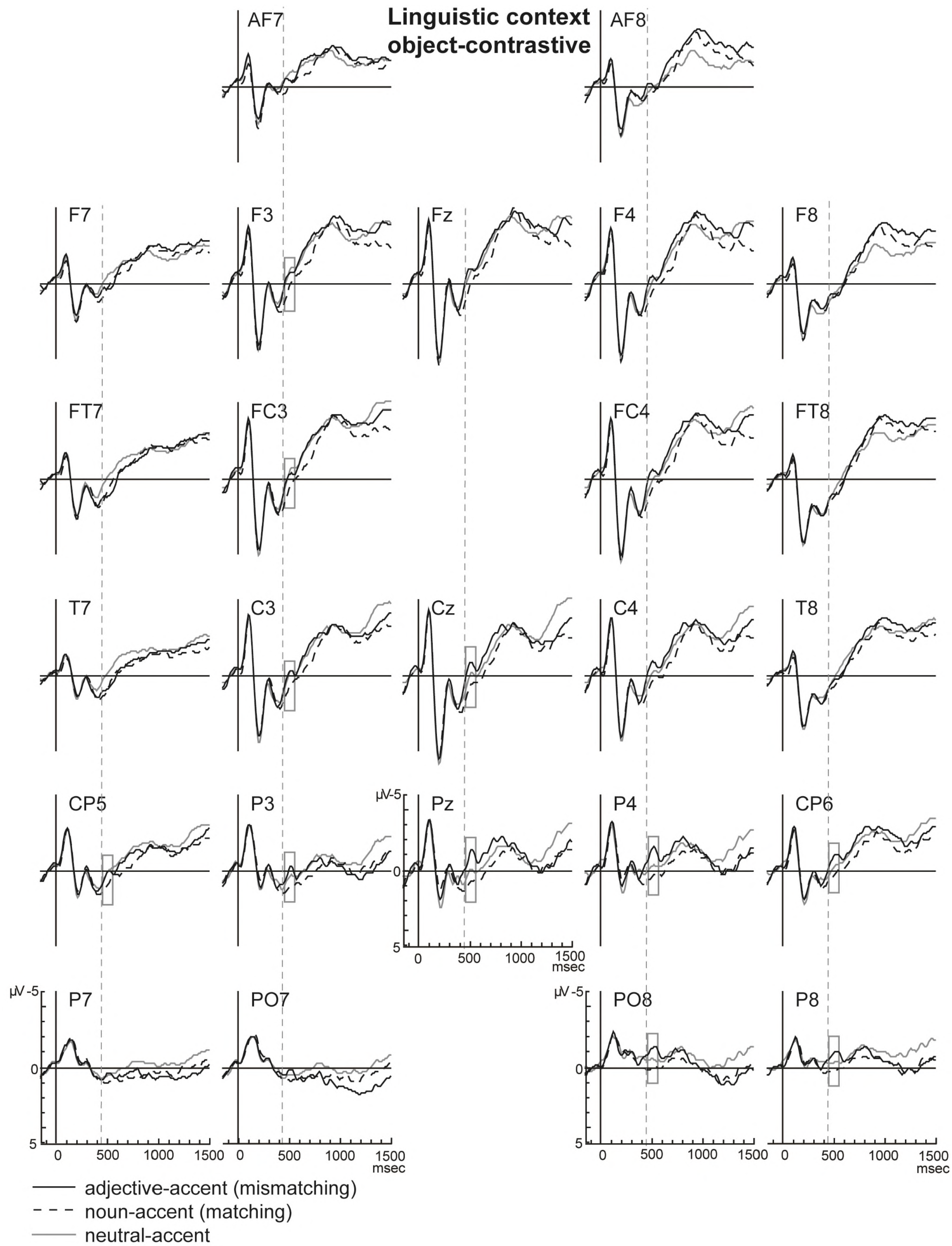


Figure 4.2 Grand average waveforms for all electrodes for the three Accent conditions (adjective-accent, noun-accent, neutral-accent) in the object-contrastive condition in the linguistic context. Dotted vertical lines indicate the average onset of the noun (412 msec). Boxes indicate time windows with significant differences between the adjective-accent and noun-accent conditions.

The late window (450-550 msec) yielded Accent by Contrast interactions in the midline ($F(1,23) = 6.10$, $p < .05$) and lateral analyses ($F(1,23) = 5.04$, $p < .05$) as well as an interaction between Accent, Contrast, Hemisphere, and ROI ($F(1,23) = 5.02$, $p < .05$). Follow-up analyses for the color-contrastive condition yielded no differences between the two Accent conditions (ps < .30). For the object-contrastive condition, a main effect of Accent was found in the midline ($F(1,23) = 5.78$, $p < .05$) and the lateral analysis ($F(1,23) = 5.88$, $p < .05$), pointing to a broadly distributed negativity for the adjective-accent (mismatch) relative to the noun-accent (match) condition for the late window.

In summary, the above analyses showed that for the color-contrastive condition an *early* negativity (300-400 msec) occurred for the mismatching accentuation condition (noun-accent). The onset of this negativity preceded the average onset of the noun (see vertical grey dotted lines in Figure 4.1). Thus, it was presumably elicited by the missing accent on the adjective. No effects were found on the noun, which carried a superfluous accent in the mismatching condition (noun-accent). Conversely, for the object-contrastive condition, we found a *late* negativity (450-550 msec) for the mismatching accentuation condition (adjective-accent), which started after the average onset of the noun (see vertical grey dotted lines in Figure 4.2). This timing suggests that this late negativity was at least partly elicited by the missing accent on the noun. However, the superfluous accent on the adjective did not yield any effect in the time window covering the acoustic duration of the adjective.

Neutral-accent conditions. In the color-contrastive condition (see Figure 4.1), during the early time window (300-400 msec) the neutral-accent condition did not differ from the adjective-accent (matching) condition (all ps > .16). In contrast, the ERPs for the noun-accent condition were more negative-going than for the neutral-accent condition. A main effect of Accent was found in the midline ($F(1,23) = 9.65$, $p < .01$) and lateral ($F(1,23) = 4.51$, $p < .05$) analyses, as well as interactions between Accent and Hemisphere ($F(1,23) = 5.77$, $p < .05$) and between Accent and Electrode ($F(3,21) = 6.45$, $p < .01$). Follow-up analyses showed a broadly distributed effect with a central maximum. In the late time window (450-550 msec), no differences between the noun-accent and neutral-accent condition were found (all ps > .20). The lateral analyses comparing the adjective-accent and neutral-accent conditions during the late window yielded an interaction between Accent and Electrode ($F(3,21) = 3.74$, $p < .05$). However, in follow-up analyses none of the electrodes showed an effect (all ps > .07). Taken together, these analyses show that the neutral-accent condition followed the pattern of the adjective-accent (matching) condition throughout the early and late time window.

In the object-contrastive condition (see Figure 4.2), the neutral-accent condition showed no differences from the adjective-accent and noun-accent conditions during the early window (all ps > .14). During the late window, the lateral analysis with the neutral-accent and the adjective-accent condition, showed an interaction between Accent and Hemisphere ($F(1,23) = 4.89$, $p < .05$). Follow-up analyses showed that only 3 left lateral electrodes yielded more negative-going ERPs for the neutral-accent condition (F7, FT7, T7, ps < .05). Comparing the noun-accent and neutral-accent conditions for the late time window, the lateral analysis showed a main effect of Accent ($F(1,23) = 4.83$, $p < .05$). Follow-up analyses showed that this negativity for the neutral-accent, relative to the noun-accent (matching) condition was also restricted to the left hemisphere, but more widely distributed (F7, FT7, T7, AF7, F3, FC3, C3, and CP5, ps $< .05$). These results suggest some processing difficulty at the noun for the neutral-accent condition, relative to the noun-accent (matching) condition.

4.2.3 ERPs for visual context

Effects of noun-accent and adjective-accent conditions. Grand average waveforms are presented for the different Accent conditions (adjective-accent, noun-accent, and neutral-accent) together, for the color-contrastive (Figure 4.3) and for the object-contrastive condition (Figure 4.4). Both figures show more negative-going ERPs for the noun-accent (black dashed line) than for the adjective-accent (black solid line) condition around 400 msec. However, this effect seems larger and more widely distributed for the object-contrastive (Figure 4.4) than the color-contrastive condition (Figure 4.3). On the basis of the time course analyses, we chose a 250-450 msec window to analyze this negativity.

The midline analysis for the 250-450 msec window showed a main effect of Accent ($F(1,23) = 16.28$, $p < .001$). The lateral analysis yielded both a main effect of Accent ($F(1,23) = 17.59$, $p < .001$) and interactions between Accent, ROI, and Electrode ($F(3,21) = 5.07$, $p < .01$) and between Accent and Electrode ($F(3,21) = 5.09$, $p < .01$). Furthermore, a trend towards an interaction between Accent, Contrast, ROI, and Electrode was present ($F(3,21) = 3.03$, $p = .05$). We, therefore, additionally analyzed the two contrast conditions separately. For the color-contrastive condition, the lateral analysis yielded an interaction between Accent and Electrode ($F(3,21) = 3.20$, $p < .05$). Follow-up analyses for the single electrodes showed a negativity for the noun-accent relative to the adjective-accent condition in three left lateralized electrodes (T7, C3, P3; ps $< .05$).

The object-contrastive condition yielded a main effect of Accent in both the midline ($F(1,23) = 13.11$, $p < .01$) and the lateral analysis ($F(1,23) = 11.65$, $p < .01$) and an Accent by ROI by Electrode interaction ($F(3,21) = 8.94$, $p < .001$). Follow-up analyses revealed a broadly distributed negativity for the noun-accent condition that was most prominent at the central midline and bilateral electrodes.

In sum, the noun-accent condition led to more negative-going ERPs than the adjective-accent condition in a time window (250-450 msec) starting before noun onset (see vertical grey dotted line, Figures 3 and 4). This effect held across both Contrast conditions in the visual context, but, as indicated by the interaction between Accent, Contrast, ROI, and Electrode, it was more pronounced and more widely distributed over the scalp for the object-contrastive condition. The latter observation shows that we did not simply observe a main effect of Accent.

Neutral-accent conditions. In the color-contrastive condition (see Figure 4.3), the neutral-accent condition went together with the noun-accent condition in the 250-450 msec window (ps $> .15$), whereas it was more negative-going than the adjective-accent condition. The lateral analysis showed an interaction between Accent, ROI, and Electrode ($F(3,21) = 4.27$, $p < .05$). Follow-up analyses for the single electrodes yielded two lateral posterior electrodes (P3, P4; ps $< .05$) that showed the effect. These results suggest some early processing difficulty for the neutral-accent condition when color was the contrastive information with respect to the visual context.

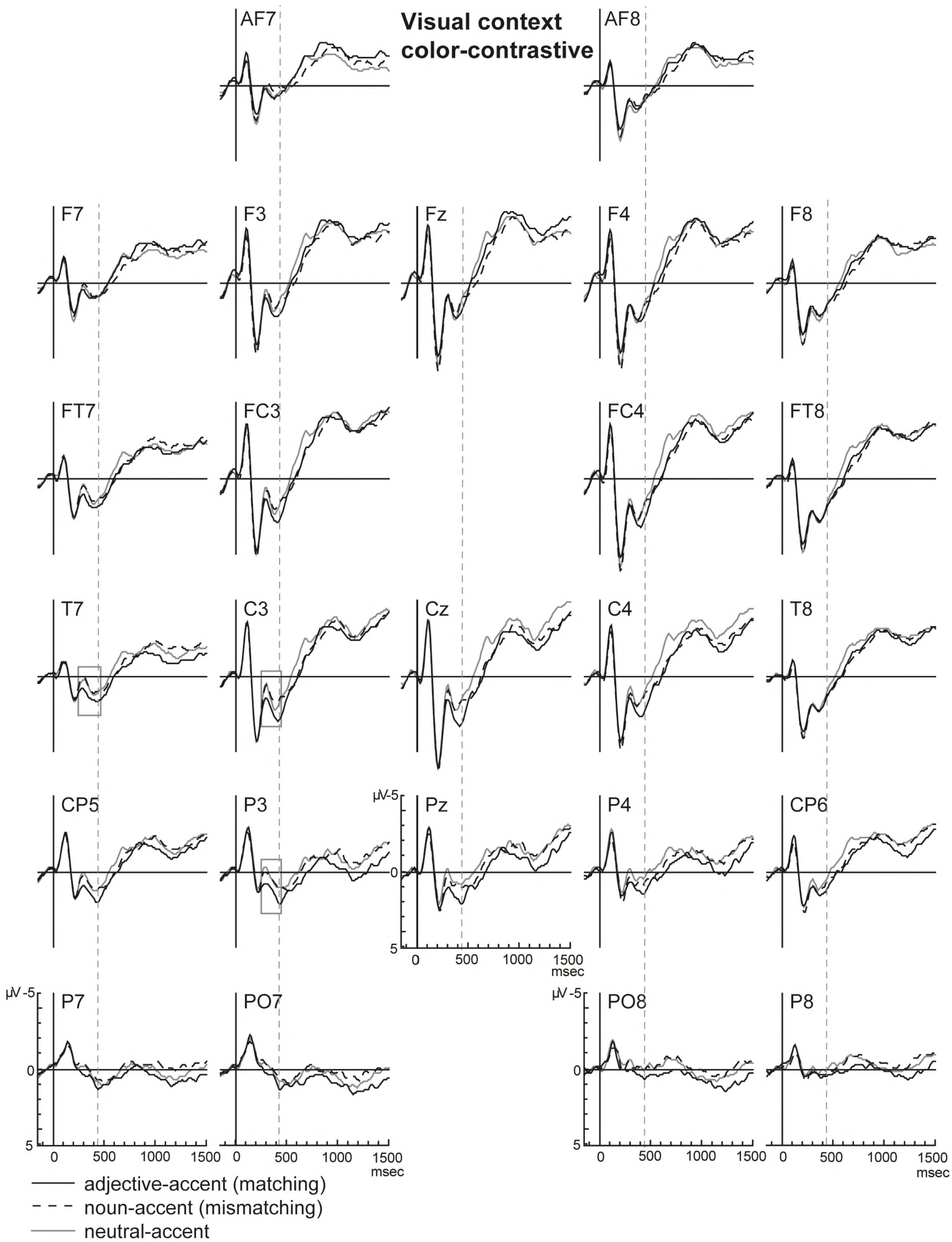


Figure 4.3 Grand average waveforms for all electrodes for the three Accent conditions (adjective-accent, noun-accent, neutral-accent) in the color-contrastive condition in the visual context. Dotted vertical lines indicate the average onset of the noun (412 msec). Boxes indicate time windows with significant differences between the adjective-accent and noun-accent conditions.

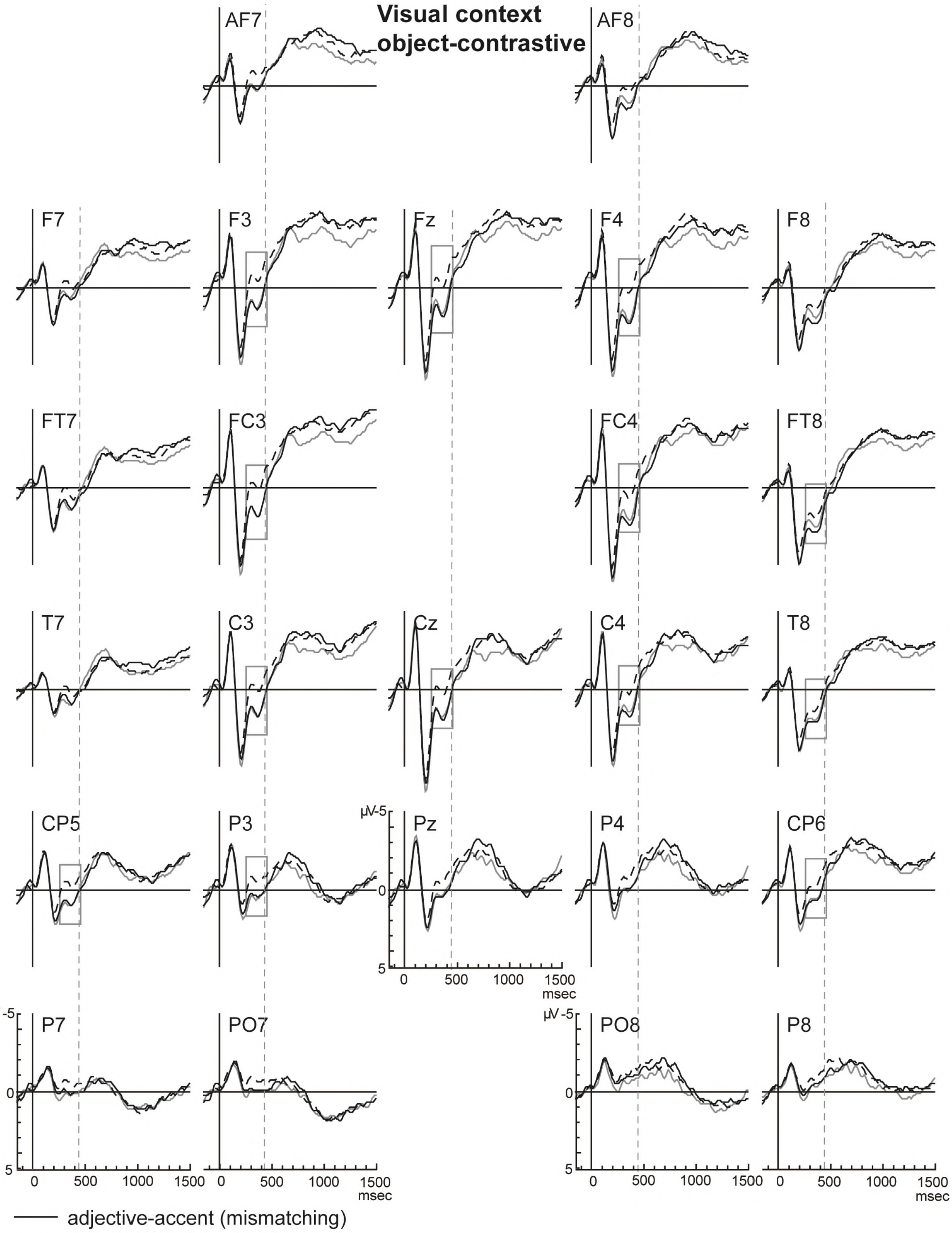


Figure 4.4 Grand average waveforms for all electrodes for the three Accent conditions (adjective-accent, noun-accent, neutral-accent) in the object-contrastive condition in the visual context. Dotted vertical lines indicate the average onset of the noun (412 msec). Boxes indicate time windows with significant differences between the adjective-accent and noun-accent conditions.

In the object-contrastive conditions (Figure 4.4), the neutral-accent condition showed no differences from the adjective-accent condition in the 250-450 msec window (ps > .20), whereas the noun-accent condition was more negative-going than the neutral-accent condition. A main effect of Accent was present in both the midline ($F(1,23) = 15.44$, $p < .001$) and the lateral analyses ($F(1,23) = 19.50$, $p < .001$). The lateral analysis also yielded an Accent by ROI by Electrode ($F(3,21) = 8.01$, $p < .001$) and an Accent by Electrode interaction ($F(3,21) = 5.04$, $p < .01$). Follow-up analyses showed a broadly distributed effect encompassing all electrodes (ps < .05) except for 6 anterior electrodes (F7, AF7, AF8, F8, FT8, and T8, ps > .09). These results suggest that the neutral-accent and adjective-accent conditions did not differ, and both showed less processing difficulty than the noun-accent condition when the object was the contrastive information with respect to the visual context.

4.3 Discussion

The present study investigated how listeners process accentuation patterns in referential utterances on-line, in relation to the linguistic or the visual context. In the linguistic context, either the adjective or the noun were contrastive, relative to the previous NP, while the other word was repeated. In the visual context, the referential NP referred to a target picture that differed from a simultaneously presented context picture with respect to either only the color or only the object.

4.3.1 Linguistic context

The NPs with a mismatching accentuation relative to the linguistic context yielded negative-going effects in the ERPs, relative to the matching accentuation patterns. When the color was the contrastive information relative to the previous trial, we found an *early* negativity in the ERPs (300-400 msec) for the mismatching NP with an accent on the noun. Since this effect preceded noun onset (which started after 412 msec on average) it is thus elicited by the adjective with a missing accent. In contrast, when the object was the contrastive information, the mismatching NP with an accent on the adjective led to a *later* negativity (450-550 msec), starting only after the average onset of the noun. Therefore, this later negativity is elicited, at least in part, by the missing accent on the noun. In the introduction of this chapter we distinguished between the Missing Accent Hypothesis and the Wrong Accent Hypothesis. The timing of the present results rules out the Wrong Accent Hypothesis since no effects were found when a superfluous accent was encountered (neither on the adjective, nor on the noun). Instead, this pattern of ERP results fully supports the Missing Accent Hypothesis since only missing accents led to processing difficulty in the form of a negativity in the ERPs. The results even support a strict immediate version of this hypothesis, in that missing accents only lead to processing difficulties at the moment they are encountered and processing returns back to normal immediately afterwards.

As described in the introduction, some previous ERP experiments on the effects of linguistic contexts during sentence processing also found processing difficulties for missing accents only (Hruska & Alter, 2004; Hruska et al., 2001; Johnson et al., 2003, Toepel et al., 2007). In contrast, other studies found problems for both missing and superfluous accents (Magne et al., 2005). The present results suggest that missing accents are particularly hard to process for listeners. In most previous ERP studies, participants were asked for every item to give a (prosodic) acceptability judgment of the target sentence. Note that listeners probably do not do this in a natural listening situation, and that ERP components might have been affected by such task demands. In the present study, we did not direct participants' attention to the prosodic information. The fact that listeners still picked up on missing accents, suggests that this effect is relatively automatic and does not depend on listeners actively attending to the prosody of the utterances. Future research will have to show under which circumstances superfluous accents also lead to processing problems.

The ERP signature found for missing accents differs between the just mentioned studies. Our finding of a negativity is in line with the majority of studies, reporting negativities for missing accents. These negativities were generally interpreted as N400 effects (Hruska et al., 2001; Hruska & Alter, 2004; Magne et al., 2005). Toepel et al. (2007) report a negativity that precedes the onset of the missing accent, but resembles the topography and shape of an N400 effect. Johnson et al. (2003) report a frontal negativity around 400 msec. Some studies (also) report positive-going effects, interpreted as a P300 (Magne et al., 2005) or a P600 (Hruska et al., 2001; Hruska & Alter, 2004). Note, however, that these studies all included a task in which participants explicitly had to judge the appropriateness of the prosody of the target sentence. It is known that the P300 and P600 components can be influenced by task demands (e.g., Donchin & Coles, 1988; Kolk et al., 2003). In the present study, not using a task which directs participants' attention on the prosody of the utterances, missing accents consistently elicited negativities. Following earlier studies (e.g., Hruska & Alter, 2004), these negativities can be interpreted as N400 effects, reflecting difficulty to integrate new information without an accent. The negativities start immediately after onset of the missing accent. This early onset is also in line with earlier studies (e.g., Toepel et al., 2007) and might be related to the predictability of an accent on the basis of earlier auditory material. However, when comparing the present study to earlier studies, one should keep in mind that previous studies on the role of accentuation concerned sentence processing in a purely linguistic setting. By contrast, in the present study, we are dealing with a referential communication setting, where displays of objects have to be related to referential NPs.

Why might listeners have problems with missing accents but less so with superfluous accents? Information that is new in the discourse is often the most important information for listeners. Accentuation of this new information may help listeners to attend to it, such that they do not miss this information. If this is the case, then *not* accenting important new information might lead to processing problems. In contrast, deaccentuation of already given information is possible because the information is known to the listener and easy to identify. However, if it *is* accented, that is, has a superfluous accent, this is not very detrimental to the listener either, since no important information is lost.

How do the results of the 'neutrally' accented NPs relate to the Missing Accent Hypothesis? Do listeners interpret intermediate accents as missing accents or not? The results show that the neutral accentuation is neither always equivalent with a contextually motivated accent, nor always equivalent with a missing accent. This suggests that contextual factors determine whether a neutral accentuation is interpreted as a missing accent.

When color was the contrastive information, a missing accent on the adjective led to processing difficulties, but a neutral accent on the adjective did not. Apparently, the neutral accent is interpreted as an accent on the adjective. It thus appears that the linguistic context is strong enough to lead listeners to 'mishear' an intermediate accent on the adjective as fitting the linguistic context, in this case as an accent on the adjective. This context-induced 'auditory illusion' is reminiscent to results in a different domain of prosody. Itzhak et al. (2010) report a CPS (reflecting the processing of a prosodic break) in a situation where no actual prosodic break was present, but where the sentence context elicited a strong expectation of a break at that position.

Conversely, when the object was the contrastive information, listeners did experience processing difficulty for a neutral accent, just as for a missing accent, on the noun. Apparently, a neutral accent was interpreted in the same way as a missing accent. The ToDI transcriptions of the neutral accentuation pattern (see Table 4.2) show that the accent on the noun is downstepped relative to that on the adjective and is thus clearly not the most prominent accent of the NP. Thus, after having heard the adjective, listeners appear to interpret the intermediate accent on the noun as a missing accent.

To summarize, the results for the linguistic context support the Missing Accent Hypothesis. Listeners experienced on-line processing difficulties for missing, but not for superfluous accents. A neutral accent early in the NP (on the adjective) was accepted as a contextually motivated accent, possibly because of an 'auditory illusion' elicited by the linguistic context. Later in the NP (on the noun), a neutral accent was interpreted as a missing accent, suggesting that the relative strengths of the accents on adjective and noun were taken into account.

4.3.2 Visual context

The results for the visual context were clearly different from those for the linguistic context; listeners did not consistently experience processing difficulty for missing accents. Rather, more negative-going ERPs were present for the NPs with an accent on the noun relative to NPs with an accent on the adjective, in a window from 250 to 450 msec. This effect was present both when the color was contrastive and when the object was contrastive relative to the simultaneous visual context.

However, the size and/or distribution of the negativity in the ERPs differed between the two contrastive contexts. When the color was contrastive, the effect was restricted to a few electrodes over the left hemisphere, whereas it was more broadly distributed over the scalp, including midline and bilateral central electrodes, when the object was contrastive. It thus appears that the results in the two contrastive contexts require different interpretations.

When color was contrastive, the ERPs showed an early negativity for the NP with an accent on the noun. This pattern is similar to the corresponding pattern in the linguistic context and suggests that a missing accent on the color adjective leads to processing difficulty. This implies that the Missing Accent Hypothesis, in this case, also holds for the visual context. The findings of the eye-tracking study by Eberhard et al. (1995), referred to in the introduction of this chapter, are consistent with this conclusion.

When the object was the contrastive information, an early negativity was elicited in the ERPs by the NP with an accent on the noun, which is inconsistent with the Missing Accent Hypothesis. To understand this negativity, one has to keep in mind that the color adjective is redundant, since only one color is present in the display. Thus, listeners might prefer only the object to be mentioned (see, e.g., Engelhardt, Bailey, & Ferreira, 2006). When the color is mentioned as well, this should thus somehow be motivated. An accent on the adjective might provide such a motivation, as it might signal that the speaker considers color an important aspect of the object, even though not with respect to the visual context. By contrast, when the adjective is not accented, the listener can infer no obvious reason for mentioning the color, leading to processing difficulty.

Because of the different explanations for the results in the two contrastive contexts, we also discuss the ERPs elicited by the neutral accentuation pattern in these contexts separately. When color was the contrastive information, the ERPs showed a negativity for a neutral accent, as well as for a missing accent, relative to a contextually motivated accent. Apparently, the neutral accent is interpreted as a missing accent in the visual context and not misheard as an accent on the adjective, as in the linguistic context. This fits with the idea, discussed above, that the linguistic context provides a strong, constraining context that can lead to an 'auditory illusion', whereas the visual context is less constraining. It agrees with our general pattern of results, showing that the linguistic context seems to be a stronger and more consistent factor in interpreting accentuation patterns than the visual context.

If the object is the contrastive information, a neutral accent on the color adjective does not show processing difficulty. Thus, some form of an accent on the adjective seems to be enough for listeners to provide a communicative reason for mentioning it, in the absence of a clear informative function. Only a clear deaccentuation of the color adjective leads to additional processing difficulty, presumably because the listener cannot infer a reason for mentioning the color information.

In summary, in the visual context, listeners do not consistently show on-line processing difficulties for missing accents. However, listeners' ERPs do show a negativity in response to a missing (and a neutral) accent on a color adjective when color was contrastive, providing some support for the Missing Accent Hypothesis in the visual context as well. However, when the color adjective was redundant with respect to the display, we found processing difficulty for a deaccented color adjective.

4.3.3 Conclusion

The present study investigates the on-line processing of accentuation patterns in referential communication, relative to contrasts in both the visual and the linguistic context. We found that listeners experience processing problems when they encounter a missing pitch accent on an element that is contrastive with respect to the preceding linguistic context. Such processing problems do not occur in the case of superfluous accents, providing support for the Missing Accent Hypothesis.

In the visual context, listeners do not consistently show processing difficulties for missing accents. However, in certain circumstances, the results support the Missing Accent Hypothesis also in the visual context. Furthermore, listeners seem to experience processing difficulty when redundant color adjectives are mentioned without a communicative motivation.

4.4 Supplementary analyses I: Effects of repetition[1]

To test whether repetition of the noun and/or the adjective from one trial to the next modulates the ERP pattern in the present data, we contrasted the same accent conditions that occurred in different linguistic contexts.

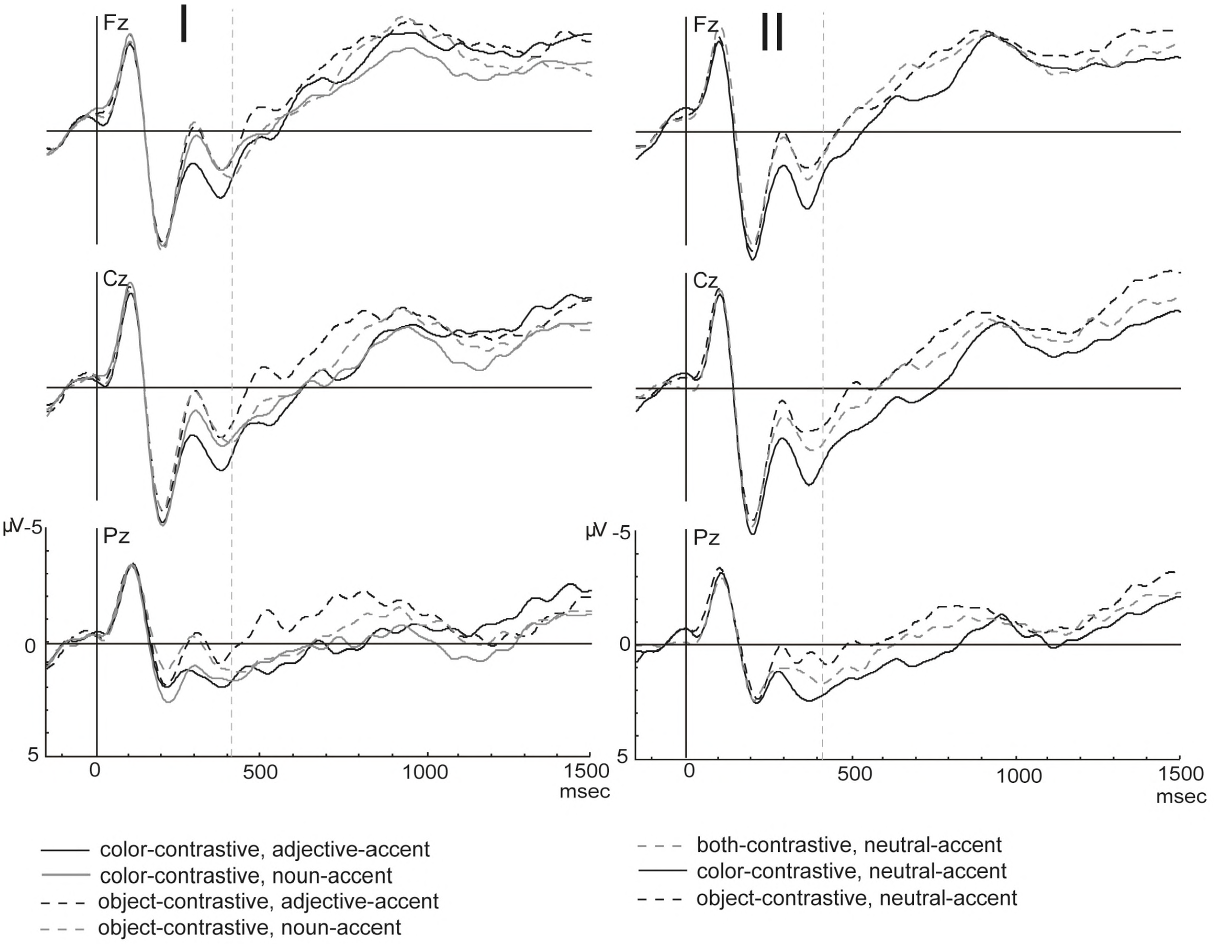


Figure 4.5 Grand average waveforms for the midline electrodes of the linguistic context items. Panel I shows the noun-accent and adjective-accent conditions in the two contrastive linguistic contexts. Panel II shows the neutral-accent conditions in a color-contrastive, object-contrastive and both-contrastive (baseline) linguistic context. Dotted vertical lines indicate the average onset of the noun (412 msec).

Figure 4.5 shows grand average waveforms for the linguistic context at the midline electrodes, in panel I for the adjective-accent and noun-accent conditions within the object-contrastive and color-contrastive conditions, and in panel II for the three neutral-accent conditions in the color-contrastive, object-contrastive and both-contrastive (baseline) condition. Table 4.4 shows the main effects of Contrast in statistical time course analyses of consecutive 50 msec time windows.

[1] These supplementary analyses are included as Appendix A in Bögels et al. (under revision).

Table 4.4 Results of the time course analyses on consecutive 50 msec windows for the linguistic context. Only effects of Contrast are reported that were significant in at least two consecutive 50 msec windows.

Analysis	**Effect**	**Time windows (in msec)**
Noun-accent/adjective-accent		
Midline	Contrast	250-350**, 700-850*
Lateral	Contrast	250-350**, 750-1150*
Neutral-accent; color vs. object		
Midline	Contrast	250-550*, 650-850*
Lateral	Contrast*Elec.	250-550*, 650-850*
Neutral-accent; color vs. both		
Midline	Contrast	650-800*
Lateral	Contrast*Elec.	300-400*
	Contrast*ROI*elec.	650-800*
Neutral-accent; object vs. both	-	-

** ps < .01, * ps < .05

The results suggest a biphasic pattern in the ERP effects. The waveforms are generally less negative-going when the noun is repeated (solid lines) than in the other conditions (dashed lines). An early effect starts at 250 msec and lasts until 350 msec for the noun-accent and adjective-accent conditions (panel I) and until 550 msec for the neutral-accent condition (panel II). A later effect starts 300 msec after average onset of the noun (700 msec after NP onset). This effect probably reflects a reduced N400 effect caused by noun repetition.

The early effects are hard to interpret, since they are modulated by an interaction with Accent (see Results section). An early onset of the noun repetition effect might be related to prediction. In the linguistic context part of the experiment, the target- and context-picture in the same display always differ in both color and object, so the noun that will follow can be predicted from the color adjective.

In contrast to the ERP effects of noun repetition, we do not find a reduced N400 effect for repetition of the color adjective. This is possibly related to a difference between the color and the object information in the present experiment (and presumably also in the outside world). Whereas the experiment contains 72 different objects, only 8 colors are used. Therefore, every individual color is repeated much more often in the course of the experiment than every individual object. Multiple repetitions of a certain word can lead to a reduction of the N400 suppression effect (e.g., Swick & Knight, 1997). That is, the suppression effect is largest for the first repetition but gets smaller for subsequent repetitions. Related to this, the N400 suppression effect is larger for infrequent than for frequent words (Kutas et al., 2006). Therefore, if repetition of color adjectives initially leads to suppression of the N400, this effect might become much smaller very soon in the present experiment, because repetition of this particular color (with or without intervening trials) frequently occurs within the experiment.

4.5 Supplementary analyses II: Effects of redundancy[2]

To see whether effects of redundancy of the color adjective and/or task effects were present in the ERPs of the visual context conditions, we contrasted the same accent conditions that occurred in different linguistic contexts.

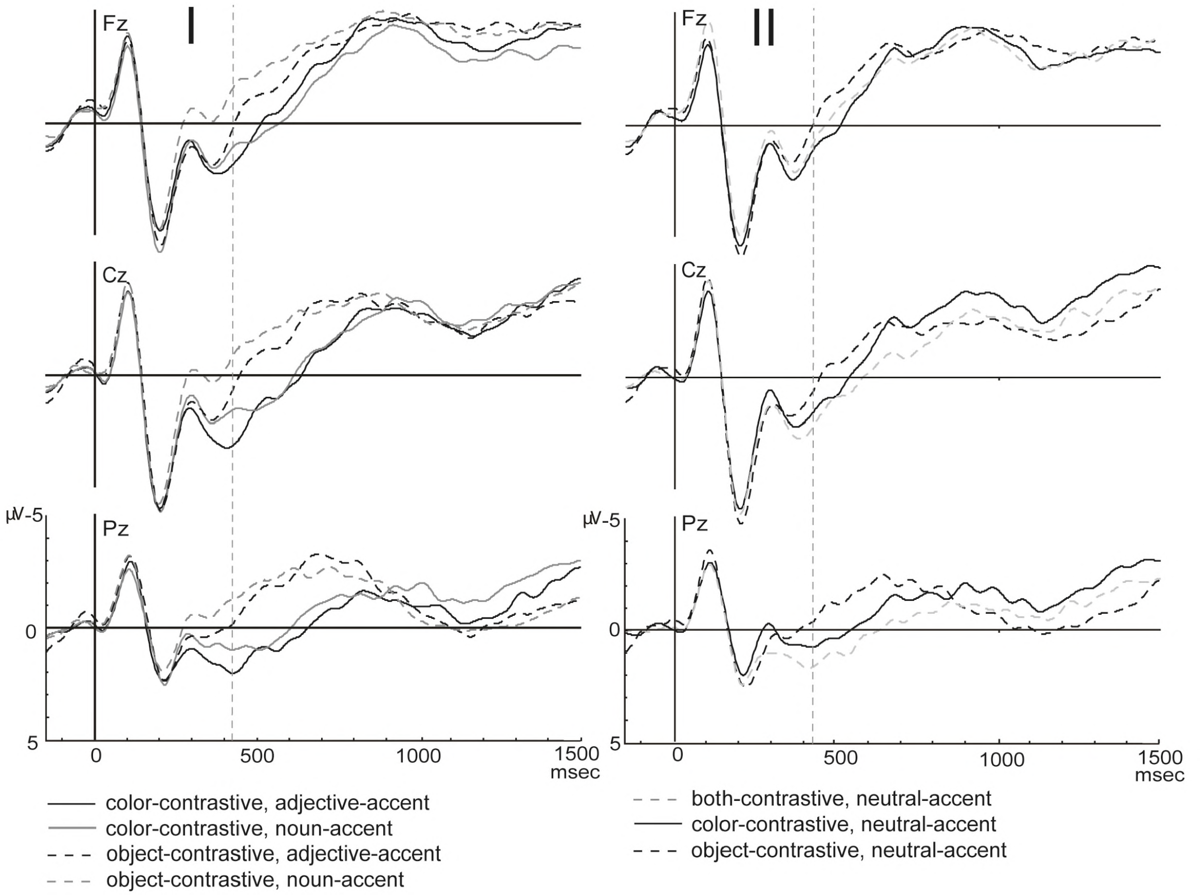


Figure 4.6 Grand average waveforms for the midline electrodes in the visual context items. Panel I shows the noun-accent and adjective-accent conditions in the two contrastive visual contexts. Panel II shows the neutral-accent conditions in a color-contrastive, object-contrastive and both-contrastive (baseline) visual context. Dotted vertical lines indicate the average onset of the noun (412 msec).

Figure 4.6 shows grand average waveforms for the midline electrodes, in panel I for the adjective-accent and noun-accent conditions within the color-contrastive and object-contrastive contexts, and in panel II for the three conditions with a neutral accent in the color-contrastive, object-contrastive and both-contrastive (baseline) condition. Table 4.5 shows the main effects of Contrast in time course analyses of consecutive 50 msec windows.

These results show more negative-going ERPs in a broad time window, from relatively early on (around 300 msec for some comparisons) until about 700 msec, for conditions including displays where the color is redundant (two different objects that have the same color), relative to conditions including displays with two different colors. This negativity in

[2] These supplementary analyses are included as Appendix B in Bögels et al. (under revision).

the ERPs might point to a processing difficulty because of the redundant color information. Mentioning a redundant color adjective might be less acceptable than mentioning a redundant noun, because the latter is the default, while the former is optional. Engelhardt et al. (2006) have already shown that redundant information in a referential utterance leads to similar off-line acceptability judgments as concise referential utterances. However, their on-line eye-tracking data showed that the unimportant information did lead to later and slower eye-movements to the target, suggesting on-line processing problems for redundant information.

Table 4.5 Results of the time course analyses of consecutive 50 msec windows for the visual context. Only effects of Contrast are reported that were significant in at least two consecutive 50 msec windows.

Analysis	Effect	Time windows (in msec)
Noun-accent/adjective-accent		
Midline	Contrast	300-750*
Lateral	Contrast	300-750*
Neutral-accent; color vs. object		
Midline	Contrast	450-650[1]
Lateral	Contrast	450-650*
Neutral-accent; object vs. both		-
Midline	Contrast	400-750[1]
Lateral	Contrast	400-750*
Neutral-accent; color vs. both		
Midline	Contrast*Elec.	500-850*

* ps < .05, [1] ps < .06

Another potential reason for the broad negativity concerns the task in this experiment, namely determining the position of the referred to object. If the two displayed objects have different colors (as in the large majority of the trials), the participants can know the position of the object as soon as they can identify the color name. However, if the two objects have the same color, participants can only identify the referred to object when hearing the name of the object. They thus have to postpone their decision until that moment. This decision delay might lead to the negativity in the ERPs, possibly related to prolonged working memory processes (see King & Kutas, 1995, for a review on ERP components related to working memory).

4.6 Production of accentuation in referential communication[3]

Above, we reported the results from an on-line language comprehension experiment, looking at the effects of matching and mismatching accentuation patterns in the visual and linguistic context. Here, we address the question whether and in what circumstances speakers actually produce these kinds of accentuation patterns.

Pechmann (1984) investigated how visual and linguistic context information affects the production of referential utterances. He first observed that the large majority of speakers in his experiment overspecified their utterances when referring to colored objects in a display. That is, they specified both the color and the object of the referent, also in cases where mentioning only the color or only the object would suffice to identify the referent. Four judges evaluated the accentuation of these overspecified referential utterances, sorting them into two categories: a pitch accent on the adjective or a pitch accent on the noun. The results showed that speakers in most cases accented the element that was contrastive (new) with respect to a previous utterance when the other element was given in that utterance. However, when the intended referent was contrastive with respect to simultaneously presented visual competitors, the large majority of the referential utterances had a pitch accent on the noun. In conclusion, Pechmann found that speakers marked contrasts in the linguistic context with a pitch accent, but not contrasts in the visual context.

Although the results of this study are very straightforward, one should keep in mind two aspects of the study. First, the participants in Pechmann's study were asked to communicate to the experimenter which picture in a display was marked as the intended referent. Since the addressee was thus the experimenter, who can be expected to know the intended referent, the participants might have been less motivated to indicate the referent as clearly as possible. Therefore, in a second experiment, Pechmann asked listeners to indicate which of four pictures they liked best. In this situation, the experimenter obviously does not know the intended picture beforehand. Nevertheless, this experiment basically replicated the results of the first experiment.

Second, the linguistic and visual context in the experiment by Pechmann (1984) differ in the saliency of the contrastive information. The linguistic context consists of the utterance that was produced by the speakers themselves. Since they has just produced this context, it would be hard for them to ignore it. In contrast, the visual context consists of the other pictures in the display. Since one of the pictures is clearly marked as the referent right from the start of the trial, it can immediately be identified as the target picture. Thus, in principle, the speakers do not have to look at or attend to the other pictures in the display. Though this concern might apply less to Pechmann's second experiment, it might still be the case that the speakers attend to only one picture, for example the picture that they fixate first.

To address the latter point, we carried out a production experiment looking at the visual context in which we focused on the potential role of attention. Via a manipulation based on an attention paradigm by Posner (1980), we made sure that, in the critical experimental trials,

[3]We would like to thank Matthias Sandmann, who gathered the data of this production study and helped designing it as part of an internship for his Bachelor's degree. This production study is not part of Bögels et al. (under revision).

speakers paid attention to both pictures in the display before naming one of them. We pre-cued the location of the target picture before the pictures themselves appeared. In most trials, the precue indicated the correct location, but in a small proportion of the trials the cue switched to the other picture shortly after the pictures appeared, forcing participants to pay attention to both pictures (for details, see Methods section, 4.6.1). Furthermore, speakers were told that their utterances were recorded, and that these utterances would later be used in a perception experiment in which listeners had to determine the referent as quickly as possible. In this way, we hoped that speakers would produce the utterances with a listener in mind.

We hypothesized that these manipulations, especially the cueing, would enhance the chances for an effect of the visual context on accentuation.

4.6.1 Methods

Participants. Participants were 15 students from the Radboud University Nijmegen. They had no visual or reading problems, did not stutter, and were not color-blind. Participants received 10 euro per hour or course credit for their participation. One of the participants was removed because of a technical error. The remaining 14 participants (11 female, 3 male) had a mean age of 22.1.

Materials. The visual two-picture displays were the same as those used in the main experiment (see section 4.1.2, visual materials).

Procedure. Participants were led to believe that they participated in the first part of a two-part experiment. They had to name pictures in such a way that other participants in the later, second part of the experiment could identify them. First, participants received an object-familiarization task, to make sure they knew the intended names for the objects. They saw an uncolored object and had to name it (e.g., *de helm*, ‘the helmet’). Then they had to press a button to see the correct written name. They were instructed to check whether this name matched their own reference. If not, they had to pronounce the written name and remember it. This object-familiarization task was followed by a short color-familiarization task in which each of the eight colors used in the experiment were presented in a rectangle after each other and participants had to name the color and rectangle (e.g., *de rode rechthoek*, ‘the red rectangle’). This color-familiarization task gave us the additional opportunity to check (for one item) whether participants mark a contrast in the linguistic context with respect to color, since the rectangle stayed the same during all the color familiarization trials (e.g., ‘the red rectangle, the blue rectangle…’).

Following the two familiarization tasks, the participants received instructions for the experiment. In each trial, they first saw a ‘frame’, consisting of the corners of a square (see Figure 4.7A). Participants were instructed to focus on the position of the frame. After 1000 msec, two pictures appeared, one of them inside the frame (see Figure 4.7B). In most of the cases (75%) the frame stayed in the same position when the pictures appeared. However, in 25% the frame switched to the other side shortly (150 msec) after the pictures appeared (see Figure 4.7C). The participants’ task was to name the picture in the frame (e.g., ‘the red helmet’). It was stressed that participants should focus on the position where the frame appeared in the beginning, since that was in most cases also the position of the picture they had to name. Participants were told to speak clearly and not too fast, since their recordings would be used in a later experiment. In that experiment, participants would hear this utterance and would have to identify the correct picture from a similar display but without the frame. The latency from the appearance of the pictures to the beginning of the participants' utterance was measured using a voice-key. The pictures were presented for 2400 msec and the inter-stimulus-interval was 1700 msec to give participants enough time to name the picture. The experiment consisted of a short practice block and 4 experimental blocks with breaks between the blocks and took about half an hour in total.

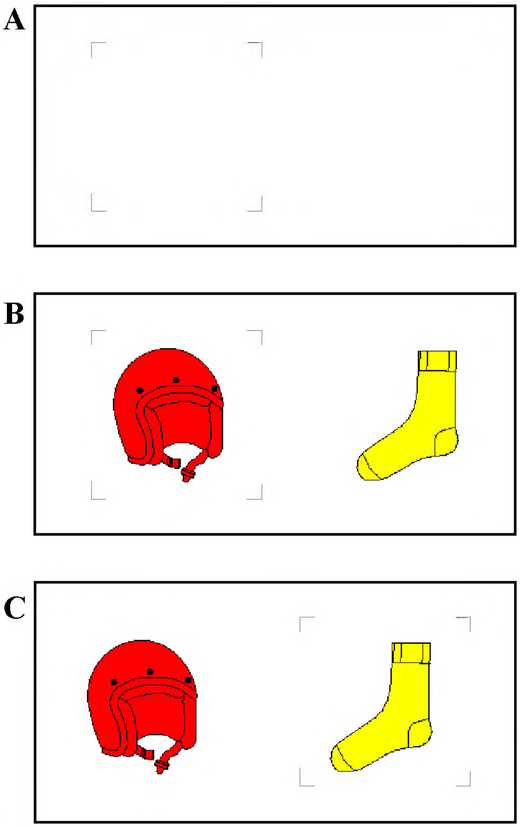


Figure 4.7 Example of a trial. First, the 'frame' (corners of a square) appeared (panel A). Then, two pictures appeared, one inside the frame (panel B). In 75% of the trials, the frame stayed at the same position (like panel B). In 25% of the cases the frame shifted to the other side 150 msec after appearance of the pictures (panel C).

Design. The experiment consisted of two crossed factors, Switch and Contrast. The factor Switch had two levels. In a no-switch trial (75% of the experimental and filler trials) the frame stayed on the same side during the complete trial. In a switch trial (25%), the frame switched to the other side shortly after the pictures appeared. The factor Contrast had three levels. In color-contrastive items, two of the same objects were shown with different colors. In object-contrastive items, two different objects were shown with the same color. In both-contrastive items, two different objects were shown with different colors. The filler items all belonged to the both-contrastive condition.

The critical trials in the experiment were the experimental switch trials in the three conditions. Each condition contained 16 switch trials (4 per block). For the experimental no-switch trials, there were 48 items per condition (12 per block). For comparison, we also analyzed 16 of these no-switch trials per condition (4 per block). To these 192 experimental items, 144 filler items were added (36 per block) of which 25% were switch trials. The practice block consisted of 12 experimental items (4 per condition) and 8 filler items; 20% of these 20 items were switch trials. In half of the trials in each condition, the target appeared on the right, and in the other half of the trials it appeared on the left side of the display.

The following restrictions applied to the randomization of the trials. Two trials with the same color and/or the same object in the display never appeared in direct succession. At least three trials separated two trials with the same object and at least one trial separated two trials with the same color. Since we did not know whether a switch trial would influence participants' performance on the next trial, two switch trials never appeared in direct succession, and the analyzed experimental no-switch trials were never preceded by a switch trial.

Data-analysis. The recordings of the participants' utterances were ordered in lists for coding by two judges. For each participant, the list started with ten filler items to get the judges used to the voice. Then, the 48 critical switch trials and the 48 critical no-switch trials followed in a random order. One of the ten filler items used at the start of the list was put in between every two experimental items, to avoid potential carry-over effects between experimental items. The judges did not know which condition each item belonged to. The color-familiarization items were put at the end of the list.

The two judges assigned each trial to one of three categories: adjective-accent, noun-accent, or neutral-accent. Their inter-rater reliability was 85.9%.

4.6.2 Results

Linguistic context item. As indicated in section 4.6.1 (Procedure), the color familiarization test can shed some light on a potential effect of the linguistic context on the production of accentuation. The familiarization test consisted of eight trials with the eight different colors and the same object (a rectangle). Since later repetitions of the same object could lead to a 'list intonation', the judges only coded the first repetition trial (which was the second trial of the familiarization test). The two judges had a 100% inter-rater reliability for these trials. The majority of the participants (i.e., 11 out of 14 participants) placed a pitch accent on the color adjective (adjective-accent), and thus accented the information that was in contrast with the preceding utterance. The remaining three participants did not display this accent pattern, but rather produced a neutral accentuation pattern.

Speech onset latencies. We analyzed the speech onset latencies to check whether the switch/no-switch manipulation was successful. All trials with onset latencies smaller than 400 msec or with voice-key failures were removed. Then, means were calculated for each condition per participant. A repeated measures MANOVA was performed on the speech onset times with Switch (switch, no-switch) and Contrast (color-contrastive, object-contrastive, both-contrastive) as within-subject factors. No difference was found between the onset times of the three contrast conditions ($F < 1$). The switch trials had longer speech onset times ($M = 1137$ msec) than the no-switch trials ($M = 981$ msec; $F(1,13) = 33.45$, $p < .001$), and this effect did not differ between the Contrast conditions ($p > .30$).

Coding of the visual context conditions. Table 4.6 shows the percentage of the three accentuation patterns per condition, for only the trials in which the judges agreed (A), the judgments of judge 1 (B), and those of judge 2 (C). The percentages in the three parts of the table differ somewhat, but overall the clearest result is the large percentage of neutral-accent categorizations in all conditions (> 84%). Thus, regardless of the visual context of the target picture and regardless of a switch of the frame or not, the participants generally produced neutral accentuation patterns. Since the percentages of adjective-accent and noun-accent categorizations were all negligibly small (which is the most important result of the study), we decided not to perform inferential statistics.

Table 4.6 Percentages of adjective-accent, noun-accent and neutral-accent categorizations per condition for trials in which the two judges were in agreement (A), for judge 1 (B), and for judge 2 (C). NS stands for no-switch trials, S for switch trials. Numbers in brackets correspond to the number of trials. Percentages corresponding to the accentuation matching the visual context are presented in bold.

A. Agreement	Color-contrastive		Object-contrastive		Both-contrastive	
	NS (196)	S (185)	NS (185)	S (183)	NS (195)	S (191)
Adjective-accent	**2.0**	**2.2**	1.6	0	1.5	0.5
Noun-accent	1.5	1.1	**2.7**	**4.4**	1.0	1.0
Neutral-accent	96.4	96.8	95.8	95.6	**97.4**	**98.4**
B. Judge 1	Color-contrastive		Object-contrastive		Both-contrastive	
	NS	S	NS	S	NS	S
Adjective-accent	**6.7**	**5.3**	2.7	5.8	3.6	5.1
Noun-accent	4.0	1.8	**7.2**	**4.8**	4.1	4.3
Neutral-accent	89.3	92.9	90.0	89.4	**92.3**	**90.6**
C. Judge 2	Color-contrastive		Object-contrastive		Both-contrastive	
	NS	S	NS	S	NS	S
Adjective-accent	**9.3**	**8.0**	5.4	3.3	3.6	7.1
Noun-accent	2.2	2.2	**7.6**	**4.3**	2.2	3.4
Neutral-accent	86.7	87.9	84.8	91.0	**89.7**	**86.6**

4.6.3 Discussion

The results from the color familiarization task showed that the majority of the participants (11 out of 14) marked a contrast in the linguistic context by a corresponding accentuation pattern (i.e., accent on the color adjective), at least in the one trial analyzed. This is in accordance with the results of Pechmann (1984). Note however, that the results in the present study come from a familiarization task before the actual experiment. Participants knew that this task was not part of the experiment, but that it was only meant to familiarize them with the colors, and they thought that no one would listen to these utterances again. Thus, even in such a completely 'non-communicative' situation, the majority of the speakers still produced a contrastive accent, showing that this effect appears to be very automatic and robust.

However, contrasts in the visual context were not marked by corresponding accentuation patterns in the large majority of the trials. Rather, more than 84% of the utterances in each condition were pronounced with a neutral intonation. Thus, the visual context did not seem to affect the accentuation of the utterances in the present experiment.

The analyses of the speech onset times show that our attention manipulation was successful. Speech onset times were longer on switch trials than on no-switch trials, indicating that, on switch trials, listeners' attention was on the initial position of the frame and had to be switched to the other side, which took some time. This suggests that the participants' attention was, at least for a small amount of time, allocated to the context picture in the switch trials. However, this attention allocation to the context picture, did not affect the accentuation patterns; the low percentages of contrastive accents hardly differed between switch and no-switch trials.

In the introduction of this section, we hypothesized that Pechmann (1984) might not have found an effect of contrasts in the visual context because of a lack of attention to context pictures. The present experiment excludes this explanation. No effect of the visual context picture on the produced accentuation patterns was found despite the fact that speakers clearly attended to the context picture. Furthermore, we tried to enhance the communicative nature of the experimental setting by leading participants to believe that they were recording the utterances for listeners in a future experiment. However, this might not have been enough, since no actual listener was present during the experiment and it might be hard for participants to imagine a future listener. Furthermore, it is not certain that the participants believed the cover story. In future research, one should enhance the communicative aspect of the experimental situation, for example by introducing a confederate of the experimenter as a 'real listener'. To make the conversation more goal-directed, some kind of communication game could be used in which speakers are motivated to help listeners in finding the right picture (see e.g., Krahmer & Swerts, 2001).

Even so, it is striking that the percentage of neutral accentuation patterns was this large; several participants (almost) exclusively used this accentuation pattern in the experiment. This might be related to the rather monotonous experimental setting and the similarity of the task in all trials. This situation might have promoted a 'monotonous' or 'list' intonation which was the same for every trial. Furthermore, the display always consisted of only two pictures. This adds to the monotonous nature of the experiment and might lead listeners to pay less attention to the other picture (irrespective of the switch manipulation).

To conclude, the present production experiment replicated the findings of Pechmann (1984) in that most participants marked a contrast in the linguistic context with a pitch accent, while in general they did not do so for contrasts in the visual context. These results show that the effect of linguistic context on the production of accentuation patterns is highly automatic and robust, and occurs under many (even non-communicative) circumstances, while an effect of the visual context is at least much more elusive. The addition of the present study is that the absence of an effect of the visual context in previous studies cannot be explained by inattention to the context pictures. Future research will have to show whether listeners do mark contrasts of the visual context in a more communicative situation.

Chapter 5

General discussion

Parts of this chapter are based on an invited paper from Language and Linguistics Compass: Bögels, S., Schriefers, H., Vonk, W., & Chwilla, D. J. (submitted). Prosodic breaks in sentence processing investigated by event-related potentials.

The present thesis investigated the effects of two different prosodic devices, prosodic breaks and pitch accents, on language comprehension. In Chapter 2, we investigated effects of prosodic breaks (PBs) on sentence processing, and in Chapter 3, we looked at the combined effects of PBs and pitch accents on sentence processing. Chapter 4 focused on effects of pitch accents in referential communication. Below, the main conclusions are discussed separately for the domain of sentence processing and for the domain of referential communication. Then, we discuss a number of general challenges and potential directions for future research on prosody in language comprehension.

5.1 Prosodic breaks and pitch accents in sentences

5.1.1 The role of PBs and pitch accents in sentence processing

In the present thesis, as in most studies on the role of PBs in sentence processing, it was assumed that PBs indicate (potential) positions for syntactic boundaries in a sentence and can thus help listeners structure a sentence. Whether an effect of a PB on the on-line processing of a sentence can be demonstrated, depends on the parsing preference of this sentence in the absence of relevant prosodic cues. For the experimental sentences used in Chapters 2 and 3 of this thesis, Steinhauer et al. (1999) assumed a specific parsing preference in the absence of prosodic cues (on the basis of syntactic principles), however, without providing a direct test of this assumption. They claimed that the PB had reversed this assumed preference. In Chapter 2, we first explicitly tested the assumed parsing preference in the absence of relevant prosodic cues. We found no specific parsing preference for one type of sentence (object-control) and further showed that a PB induced a parsing preference in these sentences. For the other type of sentences (subject-control) and for both types of sentences in Experiment 1 of Chapter 3, we found a general prosody-independent parsing preference that went in the same direction as the disambiguation signaled by the PB (and that was opposite to preferences predicted by syntactic principles). Sentences with a PB showed the same effect as sentences without relevant prosodic cues, suggesting that the PB did not strengthen the preference that was observed in the absence of a PB. PBs also affected off-line fragment completions, but these effects were small and did not lead to a reversal of preferences.

One could argue that it is questionable whether sentences 'without relevant prosodic cues' really exist, since every spoken sentence contains prosody. It is possible that the fact that no PB is present is also informative and for example indicates syntactic coherence (see also section 5.3.1). However, in the present thesis, an expectation of syntactic coherence cannot explain any of the results that were found for sentences without a PB. Thus, we found no evidence that the absence of a PB signals syntactic coherence.

In Chapter 3, we hypothesized that pitch accents might also affect grouping of words in sentences. A pitch accent emphasizes the word that bears the accent and brings it into focus. However, pitch accents can also bring more than one word into focus (Gussenhoven, 1999), thereby creating some kind of prosodic grouping of these words. The results of Chapter 3 showed that a pitch accent on a noun, in combination with a PB before this noun, created a strong tendency to group the noun and the following verb together. When this grouping turned out to be syntactically and semantically impossible (as for subject-control items), this led to a strong violation, reflected in an N400/P600 pattern. Since this effect was stronger than the N400 effect found for the sentences with only a PB and in the absence of prosodic cues, the grouping created by the pitch accent strengthened the parsing preference. By contrast, when the grouping was syntactically erroneous, but semantically plausible (as for object-control items), this led to a disappearance of processing difficulty. The grouping created by the pitch accent was thus strong enough to overrule the syntactic error and led to a semantically 'good enough' interpretation of the sentence (Ferreira et al., 2002). In conclusion, a PB and a following pitch accent worked together to create a strong grouping of words in a sentence.

Thus, in Chapters 2 and 3, we showed that prosodic breaks and pitch accents affect sentence parsing. In the absence of these prosodic cues, the parsing preference for the sentences used in our experiments cannot be explained by syntactic principles such as minimal attachment and late closure. As described in Chapter 1, semantic and discourse factors, such as verb biases, have also been found to affect sentence processing (e.g., Trueswell et al., 1993). Thus, a potential factor that we can also consider is verb biases of subject- versus object-control verbs. Since the corpus study (section 3.6) suggested that these verbs have different biases towards an implicit or explicit indirect object, these biases might have affected the parsing preferences for the sentences used in Chapter 2 and 3. For the off-line sentence completion studies (Chapter 2, Experiment 1), subject- and object-control verbs consistently showed opposite parsing preferences. For the on-line ERP studies, subject-control sentences without prosodic cues showed a consistent parsing preference. By contrast, object-control sentences without prosodic cues did not show a clear and consistent parsing preference. This pattern of results suggests that verb biases affected the parsing preference of the sentences used in Chapters 2 and 3.

So far, we identified separate and combined effects of PBs, pitch accents, and verb biases that played a role in the interpretation of the sentences used in Chapters 2 and 3. However, the factors mentioned so far do not explain the complete data pattern. For example, we still cannot fully explain the parsing preference for sentences without additional prosodic cues. In the General discussion of Chapter 3 (section 3.3), we enumerate several factors (e.g., syntactic principles, frequency of constructions, differences between the transitive and intransitive verbs) which can NOT be responsible for the parsing preference. Thus, other factors have to be at work here. However, we cannot identify these factors on the basis of the present results.

In conclusion, Chapters 2 and 3 show that several cues (PBs, pitch accents, verb biases, and other cues) influence the on-line processing of a sentence at the same time, often interacting with each other. This supports interactive, constraint-based theories which state that listeners take into account several factors simultaneously while processing a sentence.

5.1.2 Processing of PBs: the CPS

The CPS is a robust ERP component that reflects processing of the PB itself (see Chapter 1). In the three ERP studies reported in Chapters 2 and 3, we replicated the CPS as a response to the PB. We found an early onset of the CPS immediately after the average pause onset and a broad scalp distribution, extending to anterior sites. Contrasting this profile with earlier studies, some studies found an even earlier onset (e.g., Steinhauer et al., 1999). Steinhauer (2003) reports a bilateral, centroparietal scalp distribution, whereas several later studies also found an extension to anterior sites (e.g., Pannekamp et al., 2005; Pauker et al., submitted). In most of the experiments, we found an early negativity preceding the CPS, which has been reported by some other studies as well (e.g., Kerkhofs et al., 2007; Pannekamp et al., 2005; Pauker et al., submitted). This negativity is probably elicited by the boundary tone and/or prefinal lengthening of the last word before the pause, since it mostly occurs before pause onset (see also Pauker et al., submitted). In general, differences in the latency, scalp distribution, and amplitude of the CPS and the early negativity might be related to the elements of the PB and their precise acoustic realization. If the CPS reflects abstract structuring of the input, as suggested in Chapter 1, it is an interesting question which aspects of the PB elicit the CPS and are thus important for this structuring to occur. Future research will have to answer this question.

As a methodological issue, we explored different time-locking points (see section 2.4 of Chapter 2), namely sentence onset (as used by e.g., Steinhauer et al., 1999), pause onset (as used by e.g., Kerkhofs et al., 2007), and the onset of the last stressed syllable before the pause. This last time-locking point was chosen on the basis of acoustic measurements, showing that the components of a PB (prefinal lengthening and boundary tone) did not start before this last stressed syllable. For this reason, we regard this time-locking point as 'onset of the PB' and as the theoretically most appropriate time-locking point, at least as long as it is not exactly clear which elements of the PB elicit the CPS. We obtained a CPS for all three time-locking points, which shows the robustness of this ERP component. However, several considerations lead to the conclusion that the onset of the last stressed syllable before the pause is also the most appropriate time-locking point for practical reasons (see section 2.4.2 for a discussion of practical advantages and disadvantages of the time-locking points).

As a last point concerning the CPS, we want to suggest a direction for future research. As was noted by Pannekamp et al. (2005, p. 407), the CPS "has made it possible to examine at least prosodic processing at sentence level on-line and without the need of structural violations in the experimental design.". However, in the experiments of this thesis, and in the great majority of earlier ERP studies on the CPS (see Chapter 1), the focus was either on the CPS as a reflection of processing of the PB itself or on the processing consequences of the PB at some later point in the sentence. To date, only a few studies deviate from this general picture. One example is the study by Kerkhofs et al. (2007), described in Chapter 1 of this thesis. They used the CPS as a dependent measure to investigate whether syntactic and prosodic information are matched with each other right at the position of the PB. The PB elicited a larger CPS when the PB was unexpected on the basis of the earlier discourse context as compared to when it was expected. Similarly, a CPS has been found when a PB was strongly expected due to parsing preferences and verb biases, even though no PB was present in the actual acoustic signal (Itzhak et al., 2010). This result indicates that strong cues other than the PB can also lead to (prosodic) phrasing. In Chapter 2, we also found some indication for a modulation of the CPS. We found a larger CPS after object-control than after subject-control verbs. Speculatively, this might be related to differences between the biases of subject- and object-control verbs for an implicit or explicit indirect object (see section 2.3;

General discussion of Chapter 2). If this explanation is correct, a larger CPS was found when a PB was less expected, as in the Kerkhofs et al. study. However, one has to be careful in comparing the amplitude of the CPS between different items, as it could also be caused by acoustic differences between the items (see also section 3.6 showing different directions for the CPS modulation). It is safest to compare the exact same acoustic tokens, for example, embedded in different contexts (as in Kerkhofs et al., 2007). In conclusion, the few indications of CPS modulations that have been reported to date demonstrate that the CPS can provide insights into the processing *consequences* for sentence understanding right at the PB. This requires varying expectations for the upcoming syntactic structure of a sentence before the PB is processed.

5.2 Pitch accents in referential communication

As argued in Chapter 1, pitch accents intuitively seem an appropriate way to emphasize words that indicate a contrast. Chapter 4 addressed the question how listeners process such pitch accents on contrastive elements in two different kinds of context. We distinguished between two competing hypotheses: the Missing Accent Hypothesis and the Wrong Accent Hypothesis. According to the former hypothesis, listeners only experience processing difficulty when an accent on a contrastive element is missing. In contrast, the latter hypothesis predicts processing difficulty for every accent that is 'wrong'; both for missing accents on contrastive elements and for superfluous accents on non-contrastive elements.

5.2.1 Linguistic context

For the linguistic context, the results of Chapter 4 support the Missing Accent Hypothesis. Thus, for information that was new with respect to a previous utterance (e.g., *red* in the sequence: *the blue ball, the red ball*), a negativity was found in the ERPs when this information was not accented. However, when information was repeated across two consecutive utterances (e.g., *ball* in the example above) no difference was found in the ERPs between (superfluously) accented and unaccented information. Apparently, the linguistic context introduces a strong expectation for a pitch accent on a contrastive (new) element, presumably because listeners do not want to miss important information. Intermediate ('neutral') accents led to less consistent results, suggesting that listeners have trouble identifying these accents as contrastive or not. The interpretation of these 'neutral' accents seems to depend on the strength of the accent relative to other accents in the utterance. Note, however, that the Experiment in Chapter 4 was done in Dutch. Some available evidence suggests that effects of contrasts in the linguistic context on the perception and/or production of pitch accents might be absent or at least much less strong in other languages (e.g., Italian, Swerts, Krahmer, & Avesani, 2002).

5.2.2 Visual context

For the visual context, the results were less consistent than for the linguistic context. We found some support for the Missing Accent Hypothesis, but only in one of the conditions. In the other condition, the results might have been confounded by a redundancy of the color information; the word *red* does not give any information in the context of a display with a red ball and a red car (see section 4.3). In future studies, this problem might be avoided by using displays with more than two pictures. In conclusion, the visual context seems like a weaker cue for pitch accent placement than the linguistic context, which is in line with production findings (see section 4.6; we come back to this issue in section 5.3.3).

5.2.3 Comparing linguistic and visual context

One potentially important factor to explain the difference between the linguistic and the visual context is the saliency of the contrast. In the linguistic context, all properties of the context are already encoded in speech, and thus automatically salient. Therefore, the linguistic context easily affects pitch accent placement in the next utterance. In contrast, the properties of pictures in the visual context may have to be (linguistically) encoded before they can affect pitch accent distributions, which is probably not an automatic process.

Listeners (and speakers) may be more motivated to fully encode the properties of visual objects in a more natural interactive setting. As a first step in this direction, future production and comprehension studies can induce the illusion of a live interlocutor or use a confederate. To go a step further, two participants (a speaker and a listener) might play a relatively controlled communication game together (see e.g., Krahmer & Swerts, 2001). More generally, a first important challenge for future (ERP) research on the role of prosody in language comprehension and production is to create experimental paradigms that bring the laboratory situation closer to the situation of natural language use.

5.3 Challenges for research on prosodic processing

In the next sections, we will describe some challenges that arise from the present thesis for research on prosodic processing, and discuss related directions for future research.

5.3.1 Absence versus presence of prosodic devices

As Cutler et al. noted in their review in 1997 (p. 169), prosodic cues related to phrasing can either signal syntactic breaks by a PB or signal syntactic cohesion by the absence of a PB. To date, most studies on the role of prosody in sentence processing, including the studies in the present thesis, have focused on the first aspect. In contrast, whether the absence of a PB has an effect on sentence processing has hardly been tested directly. In earlier studies, the absence of a PB has often been confounded with the general parsing preference of a sentence; both pointed to the same disambiguation. Therefore it remained impossible to determine whether a certain effect was due to the absence of a PB or due to a general prosody-independent parsing preference (e.g., Kerkhofs et al., 2008; Pauker et al., submitted). In Chapters 2 and 3, we also mainly investigated whether listeners' parsing preferences changed when a PB was present in the sentence. However, as noted above, in the present thesis we did not find evidence that the absence of a PB plays a role in sentence processing. Pauker et al. (submitted) found effects of the presence and of the absence of PBs on sentence processing, but processing difficulties were larger when an inappropriate PB was present than when a PB was inappropriately absent. They proposed the Boundary Deletion Hypothesis stating that the mental deletion of a superfluous PB is more costly than the insertion of a missing PB (even if this goes against general parsing preferences).

The Boundary Deletion Hypothesis proposed by Pauker et al. (submitted) for PBs is quite the opposite of the Missing Accent Hypothesis as suggested in Chapter 4 for pitch accents. According to the Missing Accent Hypothesis, more processing difficulty is expected for missing accents than for superfluous accents, while the Boundary Deletion Hypothesis predicts the opposite pattern for PBs. As yet, it is unclear how one could account for this obvious asymmetry in the role of the absence versus presence of different prosodic devices.

5.3.2 Task effects

As described in Chapter 1, although no additional task beyond listening for comprehension is needed in ERP studies on sentence processing, participants are often instructed to perform an additional task, like a prosody judgment task or comprehension questions. These tasks presumably direct the listeners' attention to the prosody and/or syntax of the sentences. In contrast, in daily life, listeners' goal is usually to understand the main message of the utterance. In Chapters 2 and 3, we used a task that was as non-intrusive as possible. We mainly instructed participants to try to understand the sentences and to imagine what they were about. In order to check whether they followed this instruction, we added a simple sentence recognition task after every block.

In Chapter 2, we found a monophasic N400 effect as an indication of processing difficulty, while Steinhauer et al. (1999) found a biphasic N400/P600 pattern for the same types of sentences. One potential reason for this difference is the presence versus absence of a pitch accent on NP2, as discussed in Chapter 3. Alternatively or additionally, the different tasks used in the two studies might have played a role as well, since P600 effects have been found to be affected by task demands (e.g., Kolk et al., 2003). Likewise, in Chapters 2 and 3 we found no effects of the absence of a PB, while Pauker et al. (submitted) did find such an effect (although less strong than for the presence of a PB). However, Pauker et al. used an acceptability judgment task and asked listeners to indicate whether the sentence they heard was acceptable, which might lead listeners to focus on every aspect of prosody, also the absence of a PB.

We also found different results for Experiment 2 of Chapter 2 and Experiment 1 of Chapter 3, although the two experiments were almost identical, including the sentence recognition task. However, the studies differed in the filler sentences that were used. In Chapter 2, not only the experimental sentences, but also the filler sentences contained a manipulation of the presence versus absence of a PB whereas in Chapter 3 this manipulation was only present for the experimental sentences. One might expect the former filler sentences to direct the listeners' attention more to prosody, which might have led to the differences in results between the studies.

For the experiment reported in Chapter 4, we can compare the linguistic context part with earlier ERP studies looking at the role of pitch accents in question-answer pairs. In these studies, a prosody judgment task was often used, asking participants to judge whether the prosody of the answer matched the question or not. Such a task strongly focuses listeners on the prosodic structure of the utterances and urges them to think about what prosody they would expect in these contexts. Instead, in Chapter 4 we tried not to focus listeners on the prosody of the utterance. Rather, we used a task that was related to the referential communication situation in our experiment. In daily life, if a speaker refers to an object, listeners will try to identify the object. The task that we used urged listeners to do exactly that in our experiment. Differences in the tasks used might partly explain differences in results between the studies. Some previous ERP studies found processing difficulties for missing, but also for superfluous accents. As far as we know, all these studies used a prosody judgment task. One could hypothesize that such a task, since it focuses listeners on prosodic mismatches, heightens the chance that listeners experience a mismatch when encountering a missing accent as well as when encountering a superfluous accent. In contrast, if they do not consciously think about what prosody to expect, they might only experience processing difficulty when encountering a missing accent.

Overall, tasks that focus listeners on prosody might lead to stronger ERP effects and/or effects for different types of prosodic cues (e.g., the absence of PBs and superfluous pitch accents) than tasks that do not induce such a focus. In conclusion, one should be careful when choosing a task. In order to generalize to natural situations outside the laboratory, the task should match the listener's goals in daily life as closely as possible. These goals will usually not involve tasks like judging the (prosodic) naturalness of utterances.

5.3.3 Comprehension versus production of prosody

The discussion about the role of prosody in language comprehension obviously also leads to the question about its role in language production. Frazier, Carlson, and Clifton (2006) have postulated the 'rational speaker hypothesis' on the relation between language production and comprehension. This hypothesis states that a speaker uses prosody in a rational manner and a listener assumes that this is the case. Some version of this hypothesis is an (implicit or explicit) assumption behind most of the comprehension studies on prosody; it only makes sense for listeners to use prosodic information to structure and understand utterances if speakers (rationally) exploit this information to signal structure or meaning. However, this assumption leads to several predictions that still have to be tested. First, listeners should take into account individual differences between speakers. That is, a listener should rely more on PBs or pitch accents as a cue to syntactic structure or contrastive information when the respective speaker marks syntactic breaks consistently by PBs (or contrastive information by pitch accents), and should do less so for a speaker who is more 'sloppy' in this respect (e.g., a non-native speaker of the language). Put differently, listeners should adjust to 'speaker styles'. Second, listeners should interpret prosodic cues relative to other prosodic cues in the sentence. As an example from this thesis, in Chapter 4 we showed that intermediate accents are often interpreted relative to the other accents in the utterance. Also, Chapter 3 of this thesis shows that a PB can be interpreted differently depending on whether a pitch accent is present later on in the sentence. Carlson, Clifton, and Frazier (2001) showed that the off-line syntactic parsing of a locally ambiguous sentence is affected not merely by the presence of a PB at a syntactic break, but rather by whether this PB is the largest (in terms of relevant acoustic parameters) in the sentence. Third, listeners should take into account that speakers can have different reasons for providing a specific prosodic cue. For example, PBs can also be inserted for non-syntactic reasons such as before or after a very long constituent (Frazier et al., 2006) or can be a reflection of a hesitation or word-finding problem. A 'rational listener' should be less likely to interpret a PB as a syntactic break when it follows a very long constituent, or when it signals a hesitation in the utterance of the speaker. Future research is needed, for example using ERPs, to track whether the above predictions hold for on-line sentence processing.

A related question is whether speakers indeed use prosody in a ‘rational’ way in everyday conversation. Many (ERP) studies on prosodic processing used recorded speech from speakers who were explicitly instructed to produce PBs or pitch accents at ‘appropriate’ places indicated by the experimenters. For referential communication, Pechmann (1984) showed that it is easy to elicit ‘appropriate’ pitch accents from speakers in a linguistic context. However, the study by Pechmann and the production study reported in section 4.6 showed that it is much more difficult to elicit such pitch accent patterns for contrasts in a visual context. Possibly, a more natural situation is needed to elicit these patterns. Similarly, in the domain of PBs, there is considerable debate about whether naive speakers spontaneously produce the ‘appropriate’ prosodic patterns. Some researchers found it very hard to elicit those patterns when speakers were not aware of the ambiguity (Allbritton, McKoon, & Ratcliff, 1996; Snedeker & Trueswell, 2003), whereas others found that speakers in an interactive context reliably produce these prosodic cues, both in ambiguous and unambiguous sentences (Kraljic & Brennan, 2005; Schafer, Speer, Warren, & White, 2000). It is crucial, both for language production and language comprehension research, to understand under which circumstances speakers use prosodic cues to indicate syntactic and semantic information and how much variability exists between them.

Appendix I. Experimental sentences of Chapters 2 and 3

This appendix presents the experimental sentences used in Chapters 2 and 3. The sentences were always auditorily presented to participants in full for the ERP experiments and until but not including the second verb for the fragment completion experiments. Items that belong together are given in pairs; sentences with an intransitive V2 are given first and those with a transitive V2 are given second. All sentences in the ERP experiments contained a PB after the second verb; they were all presented once with and once without an additional PB after the first verb. Subject-control items (containing a subject-control verb as first verb) and object-control items (containing an object-control verbs as first verb) are presented in separate lists. Some of the items were changed for Experiment 1 and/or Experiment 2 of Chapter 3. In these cases, the changed item is given after the original item. The number in brackets following the changed item indicates whether it was used in Experiment 1 of Chapter 3, Experiment 2 of Chapter 3, or both.

Subject-control items

Antwoorden

1.
   a. De wetenschapper antwoordt de interviewer te zullen triomferen als hij weer een nieuwe ontdekking heeft gedaan.
   b. De wetenschapper antwoordt de interviewer te zullen inlichten als hij weer een nieuwe ontdekking heeft gedaan.

2.
   a. De secretaresse antwoordde de conciërge te komen om het probleem op te lossen.
   De secretaresse antwoordde de conciërge te zullen komen om het probleem op te lossen. (1&2)
   b. De secretaresse antwoordde de conciërge te vragen om het probleem op te lossen.
   De secretaresse antwoordde de conciërge te zullen vragen om het probleem op te lossen. (1)
   De secretaresse antwoordde de conciërge te zullen halen om het probleem op te lossen. (2)

Bekennen

3.
   a. De leerling bekende de leraar te hebben gespiekt tijdens het eerste uur.
   b. De leerling bekende de leraar te hebben opgesloten tijdens het eerste uur.

4.
   a. De man bekende de vrouw te hebben geflirt met haar beste vriendin.
   De automobilist bekende de agent te hebben gereden met te veel drank op. (1)
   De man bekende de agent te hebben gefietst met te veel drank op. (2)
   b. De man bekende de vrouw te hebben bedrogen met haar beste vriendin.
   De automobilist bekende de agent te hebben aangereden met te veel drank op. (1)
   De man bekende de agent te hebben aangereden met te veel drank op. (2)

Beloven

5.
   a. De voetballer belooft de trainer te excelleren en de beker te winnen.
   De voetballer belooft de trainer te zullen excelleren en de beker te winnen. (1&2)
   b. De voetballer belooft de trainer te verblijden en de beker te winnen.
   De voetballer belooft de trainer te zullen verblijden en de beker te winnen. (1&2)

6.
   a. De vrouw beloofde de stervende te zullen rouwen en hem eerbiedig te zullen gedenken.
   b. De vrouw beloofde de stervende te zullen begraven en hem eerbiedig te zullen gedenken.

Berichten

7.

a. De generaal bericht de koning te zullen capituleren en te zullen terugkeren naar het vaderland.
b. De generaal bericht de koning te zullen ondersteunen en te zullen terugkeren naar het vaderland.

8.

a. De voorzitter bericht de leden te zullen vertrekken maar niet zonder een daverend afscheidsfeest.
b. De voorzitter bericht de leden te zullen verlaten maar niet zonder een daverend afscheidsfeest.

Bezweren

9.

a. De dief bezweert de handlanger te vechten en niet zomaar de gevangenis in te gaan.
De crimineel bezweert de handlanger te zullen zwijgen en niet zomaar de gevangenis in te gaan. (1&2)
b. De dief bezweert de handlanger te verraden en niet zomaar de gevangenis in te gaan.
De crimineel bezweert de handlanger te zullen verraden en niet zomaar de gevangenis in te gaan. (1&2)

10.

a. De minister bezweert de staatssecretaris te zullen strijden tijdens het komende kamerdebat.
De minister bezweert de staatssecretaris te zullen strijden om de verkiezingen te kunnen winnen. (1&2)
b. De minister bezweert de staatssecretaris te zullen benadelen tijdens het komende kamerdebat.
De minister bezweert de staatssecretaris te zullen benadelen om de verkiezingen te kunnen winnen. (1&2)

Garanderen

11.

a. De dokter garandeerde de patiënt te zullen zwijgen en de familie niets te vertellen.
b. De dokter garandeerde de patiënt te zullen beschermen en de familie niets te vertellen.

12.

a. De rector garandeerde de lerares te zullen standhouden tegen de boze ouders.
b. De rector garandeerde de lerares te zullen beschermen tegen de boze ouders.
De rector garandeerde de lerares te zullen verdedigen tegenover de boze ouders. (1&2)

Getuigen

13.

a. De verdachte getuigt de agent te hebben geslapen en dus onschuldig te zijn aan de misdaad.
b. De verdachte getuigt de agent te hebben beschermd en dus onschuldig te zijn aan de misdaad.

14.

a. De gedaagde getuigt de rechter te hebben gelogen tijdens de vorige zitting.
De gedaagde getuigt de rechter te hebben gelogen omdat hij onder druk werd gezet. (1)
De gedaagde getuigt de rechter te hebben gelogen waar hij nu veel spijt van heeft. (2)
a. De gedaagde getuigt de rechter te hebben beledigd tijdens de vorige zitting.
De gedaagde getuigt de rechter te hebben beledigd omdat hij onder druk werd gezet. (1)
De gedaagde getuigt de rechter te hebben bespot waar hij nu veel spijt van heeft. (2)

Verklaren

15.

a. De getuige verklaarde de rechter te zullen zwijgen tijdens het proces.
De getuige verklaarde de rechter te zullen praten en negeerde vervolgens de vele journalisten. (1&2)
b. De getuige verklaarde de rechter te zullen verrassen tijdens het proces.
De getuige verklaarde de rechter te zullen verrassen en negeerde vervolgens de vele journalisten. (1)
De getuige verklaarde de rechter te zullen inlichten en negeerde vervolgens de vele journalisten. (2)

16.

a. De minister verklaart de asielzoekers te zullen onderhandelen zodat ze in Nederland kunnen blijven.
b. De minister verklaart de asielzoekers te zullen naturaliseren zodat ze in Nederland kunnen blijven.

Vertellen

17.

a. De tennisser vertelde de trainer te hebben gefaald tijdens de vorige wedstrijd.
De tennisser vertelde de trainer te hebben gefaald en daar absoluut niet trots op te zijn. (1&2)

b. De tennisser vertelde de trainer te hebben geraakt tijdens de vorige wedstrijd.
De tennisser vertelde de trainer te hebben geraakt en daar absoluut niet trots op te zijn. (1&2)

18.

a. De wielrenner vertelde de pers te rusten omdat hij erg moe was.
De wielrenner vertelde de journalisten te willen rusten omdat hij erg moe was. (1&2)

b. De wielrenner vertelde de pers te ontlopen omdat hij erg moe was.
De wielrenner vertelde de journalisten te willen ontlopen omdat hij erg moe was. (1&2)

Verzekeren

19.

a. De vrouw verzekerde de zieke te zullen overnachten in een zaaltje in het ziekenhuis.
De vrouw verzekerde de zieke te zullen overnachten zodat hij niet helemaal alleen zou zijn. (1&2)

b. De vrouw verzekerde de zieke te zullen bezoeken in een zaaltje in het ziekenhuis.
De vrouw verzekerde de zieke te zullen bezoeken zodat hij niet helemaal alleen zou zijn. (1&2)

20.

a. De studente verzekerde de docent te zullen feesten als ze haar tentamen zou halen.

b. De studente verzekerde de docent te zullen bedanken als ze haar tentamen zou halen.
De studente verzekerde de docent te zullen omhelzen als ze haar tentamen zou halen. (2)

Vragen

21.

a. Het kind vraagt de oppas te mogen winkelen in de grote stad.

b. Het kind vraagt de oppas te mogen bezoeken in de grote stad.

22.

a. De prinses vraagt de kroonprins te zingen op het publieke feest.
De prinses vraagt de kroonprins te mogen zingen zodat zij hem het hof kan maken. (1&2)

b. De prinses vraagt de kroonprins te inviteren op het publieke feest.
De prinses vraagt de kroonprins te mogen inviteren zodat zij hem het hof kan maken. (1)
De prinses vraagt de kroonprins te mogen uitnodigen zodat zij hem het hof kan maken. (2)

Waarschuwen

23.

a. De bewoonster waarschuwde de inbreker te zullen schreeuwen als hij dichterbij zou komen.

b. De bewoonster waarschuwde de inbreker te zullen belagen als hij dichterbij zou komen.
De bewoonster waarschuwde de inbreker te zullen aanvliegen als hij dichterbij zou komen. (1&2)

24.

a. De advocaat waarschuwde de officier te zullen dwarsliggen tijdens het belangrijke proces.
De advocaat waarschuwde de officier te zullen gaan dwarsliggen omdat hij de zaak niet zomaar verloren wilde laten gaan. (1)
De advocaat waarschuwde de officier te zullen strijden omdat hij de zaak niet zomaar verloren wilde laten gaan. (2)

b. De advocaat waarschuwde de officier te zullen dwarsbomen tijdens het belangrijke proces.
De advocaat waarschuwde de officier te zullen gaan dwarsbomen omdat hij de zaak niet zomaar verloren wilde laten gaan. (1)
De advocaat waarschuwde de officier te zullen dwarsbomen omdat hij de zaak niet zomaar verloren Wilde laten gaan. (2)

Zeggen

25.
- a. De hooligan zei de agent te hebben gescholden tijdens de grote vechtpartij.
  De hooligan zei de agent te hebben gescholden omdat hij zijn agressie kwijt moest. (1&2)
- b. De hooligan zei de agent te hebben uitgescholden tijdens de grote vechtpartij.
  De hooligan zei de agent te hebben uitgescholden omdat hij zijn agressie kwijt moest. (1&2)

26.
- a. De bezoeker zei de clown te hebben gelachen tijdens de circusvoorstelling.
  De bezoeker zei de clown te hebben gelachen om zijn grappen en rare fratsen. (1&2)
- b. De bezoeker zei de clown te hebben gewaardeerd tijdens de circusvoorstelling.
  De bezoeker zei de clown te hebben gewaardeerd om zijn grappen en rare fratsen. (1&2)

Zweren

27.
- a. De studente zweert de professor te zullen blokken om het tentamen te halen.
  De studente zweert de professor te zullen zwoegen om het tentamen te halen. (2)
- b. De studente zweert de professor te zullen omkopen om het tentamen te halen.

28.
- a. De heks zweert de dwergen te zullen terugkeren als ze weer genoeg kracht heeft.
  De heks zweert de dwergen te zullen lachen, als zij de laatste slag gewonnen heeft. (1&2)
- b. De heks zweert de dwergen te zullen betoveren als ze weer genoeg kracht heeft.
  De heks zweert de dwergen te zullen uitlachen, als zij de laatste slag gewonnen heeft. (1&2)

Object-control items

Adviseren

29.
- a. De huisarts adviseerde de vrouw te sporten om wat gewicht te verliezen.
- b. De huisarts adviseerde de vrouw te motiveren om wat gewicht te verliezen.

30.
- a. De chirurg adviseerde de vrouw te slapen voor de ingrijpende operatie.
  De chirurg adviseerde de vrouw te slapen voordat ze onder het mes zou moeten. (1&2)
- b. De chirurg adviseerde de vrouw te ondersteunen voor de ingrijpende operatie.
  De chirurg adviseerde de vrouw te ondersteunen voordat ze onder het mes zou moeten. (1&2)

Bevelen

31.
- a. De commandant beval de soldaat te vuren en het lijk op te ruimen.
- b. De commandant beval de soldaat te vermoorden en het lijk op te ruimen.

32.
- a. De commissaris beval de agent te spioneren om meer van de zaak te weten te komen.
- b. De commissaris beval de agent te bespioneren om meer van de zaak te weten te komen.

Gebieden

33.
- a. De koning gebood de ridder te knielen tijdens het uitbundige overwinningsfeest.
  De koning gebood de schildknaap te knielen waarna hij hem tot ridder sloeg. (1&2)
- b. De koning gebood de ridder te belonen tijdens het uitbundige overwinningsfeest.
  De koning gebood de schildknaap te belonen waarna hij hem tot ridder sloeg. (1&2)

34.
- a. De hertogin gebood de chauffeur te claxonneren omdat er zich een noodgeval had voorgedaan.
- b. De hertogin gebood de chauffeur te verwittigen omdat er zich een noodgeval had voorgedaan.

Gelasten

35.

a. De minister gelastte de toehoorder te vertrekken van de publieke tribune.
b. De minister gelastte de toehoorder te verwijderen van de publieke tribune.

36.

a. De rechter gelast de aanwezigen te zwijgen omdat ze de rechtsgang beletten.
   De rechter gelast de aanwezigen te zwijgen omdat ze anders de rechtsgang beletten. (1&2)
b. De rechter gelast de aanwezigen te verwijderen omdat ze de rechtsgang beletten.
   De rechter gelast de aanwezigen te verwijderen omdat ze anders de rechtsgang beletten. (1&2)

Helpen

37.

a. De verpleegster hielp de zieke te lopen omdat hij na de behandeling nog te zwak was.
   De verpleegster hielp de zieke te lopen zodat de familie niet langer hoefde te wachten. (1&2)
b. De verpleegster hielp de zieke te vervoeren omdat hij na de behandeling nog te zwak was.
   De verpleegster hielp de zieke te vervoeren zodat de familie niet langer hoefde te wachten. (1&2)

38.

a. De bewaker hielp de crimineel te ontsnappen uit de beruchte gevangenis.
   De bewaker hielp de moordenaar te ontsnappen uit de beruchte gevangenis. (1&2)
b. De bewaker hielp de crimineel te bevrijden uit de beruchte gevangenis.
   De bewaker hielp de moordenaar te bevrijden uit de beruchte gevangenis. (1&2)

Ontraden

39.

a. De bankmedewerker ontraadde de klanten te beleggen in dit slechte economische klimaat.
   De bankmedewerker ontraadde de manager te beleggen en wees op de negatieve gevolgen. (1&2)
b. De bankmedewerker ontraadde de klanten te benadelen in dit slechte economische klimaat.
   De bankmedewerker ontraadde de manager te benadelen en wees op de negatieve gevolgen. (1&2)

40.

a. De chirurg ontraadde de patiënte te ontbijten voor de zware operatie.
   De chirurg ontraadde de patiënte te ontbijten zodat ze zich kon voorbereiden op de ingreep. (1&2)
b. De chirurg ontraadde de patiënte te vermoeien voor de zware operatie.
   De chirurg ontraadde de patiënte te vermoeien zodat ze zich kon voorbereiden op de ingreep. (1&2)

Smeken

41.

a. De actrice smeekte de regisseur te volharden tot na de première van de film.
   De actrice smeekte de regisseur te volharden omdat ze heimelijk verliefd op hem was. (1&2)
b. De actrice smeekte de regisseur te behouden tot na de première van de film.
   De actrice smeekte de regisseur te behouden omdat ze heimelijk verliefd op hem was. (1&2)

42.

a. De fan smeekte de zanger te komen om op het feest te zingen.
b. De fan smeekte de zanger te boeken om op het feest te zingen.
   De fan smeekte de zanger te verzoeken om op het feest te zingen. (2)

Verbieden

43.

a. De dictator verbood de burger te liegen tijdens het belangrijke verhoor.
   De dictator verbood de burger te liegen en gaf verdere orders aan de bewakers. (1&2)
b. De dictator verbood de burger te pijnigen tijdens het belangrijke verhoor.
   De dictator verbood de burger te pijnigen en gaf verdere orders aan de bewakers. (1&2)

44.

a. Het schoolhoofd verbood de kinderen te praten tijdens de rekentoets.
   Het schoolhoofd verbood de kinderen te praten en ging verder met zijn ronde langs de klassen. (1&2)
b. Het schoolhoofd verbood de kinderen te verontrusten tijdens de rekentoets.
   Het schoolhoofd verbood de kinderen te verontrusten en ging verder met zijn ronde langs de klassen. (1&2)

Verplichten

45.

a. De directeur verplicht de werknemers te pauzeren als ze te veel fouten maken.
   De directeur verplicht de arbeiders te pauzeren als ze te veel fouten maken. (1&2)

b. De directeur verplicht de werknemers te ontslaan als ze te veel fouten maken.
   De directeur verplicht de arbeiders te ontslaan als ze te veel fouten maken. (1&2)

46.

a. De arts verplicht de zieken te rusten voordat ze een grote ingreep ondergaan.

b. De arts verplicht de zieken te ontsmetten voordat ze een grote ingreep ondergaan.

Verzoeken

47.

a. De chef verzocht de werknemer te vertrekken omdat het slecht ging met het bedrijf.

b. De chef verzocht de werknemer te ontslaan omdat het slecht ging met het bedrijf.

48.

a. De brandweerman verzoekt de omstanders te wijken om de brandweerauto doorgang te geven.

b. De brandweerman verzoekt de omstanders te verwijderen om de brandweerauto doorgang te geven.

Appendix II. Materials used in Chapter 4

Table I presents the names of the experimental objects used in the items of Chapter 4. Table II presents the names of the filler objects used in Chapter 4. In both tables, the second column gives the Dutch word and the third column gives the English translation. Pairs of objects in the items were formed from objects within the same group (same number in the first column).

Table I Names of the experimental objects with their English translations.

Group	Dutch name	English translation
1	bal	ball
1	fles	bottle
1	jas	jacket
1	lamp	lamp
2	fluit	flute
2	kam	comb
2	schoen	shoe
2	bank	couch
3	sok	sock
3	tas	purse
3	pen	pen
3	bel	bell
4	schroef	screw
4	boog	bow
4	klok	clock
4	riem	belt
5	bril	glasses
5	deur	door
5	schaats	skate
5	tol	top
6	kaars	candle
6	pijp	pipe
6	tent	tent
6	broek	trousers
7	knoop	button
7	hoed	hat
7	fiets	bike
7	vork	fork
8	vlag	flag
8	hark	rake
8	laars	boot
8	stoel	chair
9	helm	helmet
9	rok	skirt
9	slee	sled
9	vaas	vase

10	pan	pan
10	step	scooter
10	wieg	cradle
10	trui	sweater
11	pijl	arrow
11	trap	stairs
11	klomp	wooden shoe
11	muts	bonnet
12	zak	bag
12	pet	cap
12	schaar	scissors
12	jurk	dress

Table II Names of the filler objects with their English translations.

Group	Dutch name	English translation
13	kom	bowl
13	plank	shelf
13	speld	pin
13	tang	pliers
14	dolk	dagger
14	kraan	tap
14	pop	doll
14	boot	boat
15	ster	star
15	taart	cake
15	bus	bus
15	mand	basket
16	ton	barrel
16	harp	harp
16	kast	closet
16	schep	shovel
17	trein	train
17	spuit	syringe
17	muur	wall
17	kroon	crown
18	rits	zipper
18	schelp	shell
18	boor	drill
18	veer	feather

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Summary

The main aim of this thesis was to investigate how prosody affects language understanding. Prosody is the collective term used for auditory properties of spoken language, such as pauses in speech, the intonation or 'melody' of the utterance and the speed and loudness with which words are spoken. Prosody can be an important source of information. For example, the sentence *John and my sister are getting married* can imply very different things, depending on whether it is spoken with a happy or sad intonation, in a neutral or ironic tone, or with a statement (flat) versus question intonation (rising at the end).

In this thesis, we focused on two specific prosodic devices: prosodic breaks and pitch accents. A prosodic break consists of a pause or silence in a sentence, which is preceded by a certain intonation (boundary tone) and lengthening of the word before the pause. A pitch accent on a word makes this word stand out in the sentence, because it is pronounced with a higher pitch, and/or is louder and/or longer than other words. We investigated the effect of these two prosodic devices in two domains of language comprehension: sentence comprehension and referential communication. In Chapter 2, we focused on the role of prosodic breaks in the understanding of sentences. In Chapter 4, we addressed the role of pitch accents in the comprehension of references to objects. In Chapter 3, we looked at the combined influence of prosodic breaks and pitch accents on sentence comprehension.

In the study of sentence processing, researchers have made extensive use of locally ambiguous sentences, which can be interpreted in two different ways up to a certain point in the sentence. Examples of the Dutch items used in Chapters 2 and 3 are given in (1) and (2) (with literal and real English translations).

1. De leerling bekende de leraar te hebben gespiekt.
   The pupil confessed the teacher to have cheated. (literal translation)
   The pupil confessed to the teacher to have cheated. (real translation)

2. De leerling bekende de leraar te hebben opgesloten.
   The pupil confessed the teacher to have locked up. (literal translation)
   The pupil confessed to have locked up the teacher. (real translation)

The word order of the last two constituents in (2) is reversed in Dutch as compared with English. Therefore, in Dutch, (1) and (2) are ambiguous up to the second verb (*cheated/locked up*), which disambiguates the sentence. In (1) this verb is intransitive (*cheated*): one cannot cheat *someone*. Therefore, *cheated* cannot take *the teacher* as its object and thus *the teacher* is the indirect object of *confessed*; the pupil confesses the cheating to the teacher. In contrast, in (2) the second verb is transitive (*locked up*): you have to lock *someone* up. Therefore, *the teacher* is the direct object of the transitive verb *lock up*; the teacher was locked up.

Before the disambiguating word (here: the second verb) is reached, one can already start to interpret the sentence in one of the two ways. If this initial interpretation does not match the disambiguation of the sentence, this leads to processing problems at the disambiguating word (i.e., the second verb in (1) and (2)). In reading studies, such problems lead readers to slow down on this word. With these reading studies, researchers have shown that the initial

interpretation of a locally ambiguous sentence can be affected by factors related to the grammatical structure of the sentence, to the meaning of the words in the sentence, and to the discourse context. However, when one wants to study effects of prosody, reading studies are not an option, since overt prosody only exists in the auditory modality. To study sentence processing in the auditory modality, event-related brain potentials are an excellent tool, because they allow one to measure the processing of complete sentences on-line, at the moment that the listener hears the sentence, without the need of an additional task.

Some previous ERP studies have looked at the role of prosodic breaks in sentence processing, for example a study by Steinhauer, Alter, and Friederici (1999). They used German sentences with the same grammatical structure as (1) and (2). They hypothesized that a prosodic break after *confessed* would separate *confessed* from *teacher* and thus indicate that *teacher* is not the indirect object of *confessed*. Therefore, a prosodic break would make (2) easier and (1) more difficult to understand. Indeed, when they presented (1) with a prosodic break after the first verb, they found processing problems at the disambiguating verb (*cheated*). These problems were reflected in the ERPs as an N400 (related to integrating the word in the sentence context) and a P600 (related to reanalysis of the sentence), described in Chapter 1. Furthermore, when listeners processed the prosodic break itself, the ERPs showed a closure positive shift (CPS), a positive wave related to the prosodic closure of the part of the sentence before the prosodic break.

In Chapter 2, we report on a study that addresses some shortcomings of the study by Steinhauer et al. (1999). The first verb in (1) and (2) (*confessed*) is a so-called subject-control verb. This means that the subject of this verb (*the pupil*) should also be interpreted as the subject of the second verb in the sentence (e.g., *cheated*); the pupil cheats. In contrast, the first verb in example (3) and (4) (*advised*) is a so-called object-control verb.

3. De chirurg adviseerde de vrouw te slapen.
   The surgeon advised the woman to sleep. (literal and real translation)

4. De chirurg adviseerde de vrouw te ondersteunen.
   The surgeon advised the woman to support. (literal translation)
   The surgeon advised [someone] to support the woman. (real translation)

Advised is an object-control verb, because its (indirect) object should be interpreted as the subject of the second verb in the sentence. In (3), the *woman* is the indirect object of advised and the subject of *sleep*; the woman is advised and should sleep. In (4) the situation is somewhat more complicated because the indirect object of *advised* is left implicit (indicated by *[someone]* in the real translation). However, this implicit ‘someone’ is also the subject of *support*; this person is advised and should support the woman. Thus, sentences with subject- and object-control verbs superficially look very similar, while their underlying structure is different. Although Steinhauer et al. (1999) used both types of control verbs in their experiment, they collapsed the data across the two types of control verbs. In the present thesis, we looked at the different control verbs separately, and showed that they are processed differently.

Second, Steinhauer et al. (1999) did not establish the initial parsing preference for these sentences in the absence of prosodic cues. Therefore, they could not establish whether a prosodic break actually had changed this initial preference. In Chapter 2, we first investigated this 'default' initial preference with a fragment completion task. Participants heard or read the ambiguous part of sentences like (1) to (4) (not including the second verb) and then had to complete the sentences. Subject-control sentences, like (1) and (2), were more often completed with transitive verbs (like *lock up*), whereas object-control sentences, like (3) and (4), were completed more often with intransitive verbs (like *sleep*). Chapter 2 also reports on an ERP study. In contrast to Steinhauer et al., we used not only sentences with a prosodic break after the second verb, but also sentences without a prosodic break. For subject-control sentences, like (1) and (2), we found processing problems (an N400) for the intransitive disambiguating verb (*cheated*) irrespective of whether a prosodic break after *confessed* was present or absent. Thus, the parsing preference for these sentences is the same with and without a prosodic break. For object-control sentences, like (3) and (4), we also found processing problems for the intransitive verb (*sleep*), but only when a prosodic break after *advised* was present. When the prosodic break was absent, we found no differences between (3) and (4). Thus, listeners appear to have no parsing preference in the absence of prosodic cues, but a prosodic break leads to a preference for a transitive second verb.

In Chapter 3, we investigated whether not only prosodic breaks, but also pitch accents can affect the interpretation of sentences. We hypothesized that pitch accents can also group words in sentences together, just as prosodic breaks do. Pitch accents normally emphasize new or important words in a sentence and thereby bring them into focus for the listener. For example, the answer in (6) is appropriate to the question (5a) because the accented word *JOHN* (accents are indicated with capital letters) is new information with respect to the question.

5. a. Who has fallen?
   b. What happened?
6. JOHN has fallen.

However, sometimes a pitch accent does not bring just one word into focus, but also adjacent words. The answer in (6) may also be an appropriate answer to the question in (5b) although now all the words in (6) provide new information. Apparently, the accent on *JOHN* can bring all the words in this sentence into focus. This is possible because John is an argument (subject) of has fallen. In this way, words can be grouped because they are brought in focus by the same pitch accent.

We performed an ERP study in which we presented sentences such as (1) to (4) both with a prosodic break after the first verb and with a pitch accent on the second noun (*the teacher/the woman*). Together with the prosodic break, this pitch accent brings both this noun and the following verb into focus and thereby groups the second noun and the second verb together. In (2) and (4) this grouping is unproblematic, because the noun is the direct object of the disambiguating verb. However, in (1) *teacher* and *cheated* cannot be grouped together since *teacher* does not have any relation to *cheated*. Indeed, the grouping created by the pitch accent led to a strong processing problem on *cheated* (N400 and P600). In (3), *woman* is syntactically not related to *sleep*. However, if one regards the meaning of the sentence, *woman* is the subject of *sleep*: the woman should sleep. This led to a disappearance of the processing difficulty on *sleep*. We concluded that the pitch accent on the noun was a strong cue to group these words together and that, in sentences like (3), this led to a 'good enough' interpretation of the sentence that was mainly based on the meaning of the sentence and not on the syntactic structure.

We can conclude from Chapters 2 and 3 that it is important to establish the parsing preference of sentences without prosodic cues, before one can see whether prosodic cues change this interpretation. For object-control sentences, Chapter 2 showed that the prosodic break can induce a parsing preference. Chapter 3 showed that pitch accents can also influence the initial interpretation of a sentence by grouping the words in the sentence in a certain way. Future studies will have to show the relative role of prosodic breaks, pitch accents, and their combination in this process. In Chapter 2 we found that off-line studies (such as fragment completion tests) and on-line studies (such as ERP studies) can lead to different results. Furthermore, both chapters showed that the processing of subject- and object-control sentences differs considerably. The corpus-study in section 3.6 of Chapter 3 suggests that this difference might be related to the syntactic structure of sentences in which subject- and object-control verbs usually occur. Finally, we replicated the finding of a CPS as an ERP response to prosodic breaks. We showed that this is a robust ERP component that is elicited in the ERPs using different quantification procedures (see section 2.4).

In Chapter 4, we focused on the role of pitch accents in the domain of referential communication. When a speaker refers to an object, listeners should be able to identify this object. Intuitively, it should be easier for listeners to identify the intended object among other objects when it is contrasted with these other objects. For example, when referring to a car you can contrast it with other cars in the environment (we refer to this as the visual context). If the other cars have different colors, you can explicitly mark this contrast with a pitch accent: *I mean the RED car*. Alternatively, you can contrast the intended car with a car that was previously mentioned in the conversation (we refer to this as the linguistic context): *You have a yellow car, but I have a RED car*. Our main research question was how listeners process pitch accents that mark contrasts in these two kinds of context.

We conducted an ERP study with a simple set-up. A trial consisted of a visual display with two colored objects, followed by an auditory utterance referring to one of these objects. In linguistic context items, a contrast was created with the preceding utterance. For example, a sequence of two utterances like *the blue ball, the yellow ball* created a contrast on the color (see Figure 1A). We hypothesized that, in the second utterance, listeners would expect the color to be accented (*the YELLOW ball*), while a pitch accent on the object (*the yellow BALL*) would lead to processing difficulty.

In visual context items, a contrast was created with the simultaneous visual context, that is, the other object in the display (e.g., a yellow ball and a blue ball in the display, see Figure 1B). Our expectations in terms of the processing of pitch accents were similar here. Note that in the 'incorrectly' accented utterances (indicated in red in Figure 1) an accent is always missing on one word (e.g., the color, *yellow*) since this is contrastive information, and a superfluous accent is present on the other word (e.g., the object, *BALL*) since this information is not contrastive. We posed two competing hypotheses: the Missing Accent Hypothesis, stating that only missing accents lead to processing difficulty, and the Wrong Accent Hypothesis, stating that both missing and superfluous accents lead to processing difficulty.

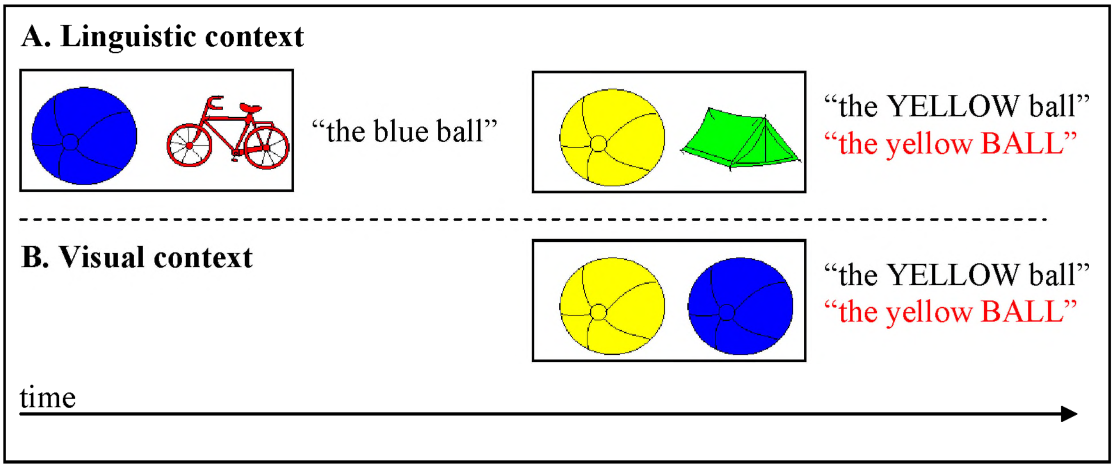


Figure 1 Example of a linguistic context item (panel A) and a visual context item (panel B). In the linguistic context, the color of the mentioned object (*yellow*) contrasts with the color in the previous utterance. In the visual context, the color of the mentioned object (*yellow*) contrasts with the color of the other object in the display. The 'correctly' accented utterances are indicated in black and the 'incorrectly' accented utterances in red.

For the linguistic context, we found evidence for the Missing Accent Hypothesis; missing accents led to processing difficulty (negativity) in the ERPs, but superfluous accents did not. Apparently, it is important for listeners that new information is accented, since this is the important information they should attend to. For given information, it appears not to matter whether it is accented or deaccented, since this information is already known.

For the visual context, we found a less consistent pattern of results. When the color was the contrastive information (as in Figure 1B) we found support for the Missing Accent Hypothesis, just as for the linguistic context. However, when the object was the contrastive information (e.g., a display with a yellow ball and a yellow hat), the results were potentially confounded by the fact that the color information is redundant in this case. Here, we found a negativity for deaccentuation of the color, possibly because an accent on the color gives a reason for mentioning this redundant information anyway. In general, the pattern of results for the visual context was less clear than for the linguistic context. This is in line with a production study by Pechmann (1984), showing that speakers mark contrasts in the linguistic context with pitch accents, but do not mark contrasts in the visual context with accents. In section 4.6 of Chapter 4 we report a small production study that aimed to investigate whether contrasts in the visual context can lead to pitch accents when they are brought under the attention of the speaker. This was not the case. Possibly, visual contexts will only affect the production and/or perception of pitch accents in a more interactive and communicative context.

As a methodological issue, although ERP studies do not require the use of a task, most ERP studies nevertheless use such a task. In this thesis, we tried to use a task (and instruction) that would focus the listeners as much as possible on the goal that they have in daily language processing. In Chapters 2 and 3 we asked them to try to understand the sentences and in Chapter 4 their task was to find the referent of the utterance. In some cases, this might have led to more subtle and/or different effects than have been found in other ERP studies using tasks that would usually not occur outside the laboratory (e.g., prosody judgment).

In conclusion, we show that prosody (in the form of prosodic breaks and/or pitch accents) plays an important role in two domains of language processing. First, listeners use both prosodic breaks and pitch accents to determine how words in a sentence should be grouped together. Second, listeners find it important that new (and contrastive) information is accented by speakers.

Samenvatting

Hoe prosodie taalbegrip beïnvloedt is de vraag die centraal staat in dit proefschrift. Prosodie is de verzamelnaam voor auditieve signalen in gesproken taal, zoals de pauzes in spraak, de intonatie of 'melodie' van een uiting en de snelheid en geluidssterkte waarmee woorden worden uitgesproken. Prosodie kan een belangrijke bron van informatie zijn. Zo kan de zin: *Jan gaat trouwen met mijn zus* bijvoorbeeld heel verschillende betekenissen hebben, afhankelijk van hoe de zin wordt uitgesproken: met een vrolijke of verdrietige intonatie, op een neutrale of ironische toon, met een stellende intonatie (vlak) of met een vraag-intonatie (omhooggaand aan het einde).

In dit proefschrift hebben we ons gericht op twee specifieke prosodische middelen, namelijk de prosodische grens (in het Engels: prosodic break) en het accent (in het Engels: pitch accent). Een prosodische grens bestaat uit een pauze of stilte in een zin, die wordt voorafgegaan door een bepaalde intonatie (vaak stijgend) en verlenging van het woord vóór de pauze. Een accent op een woord laat dit woord opvallen in de zin, doordat het hoger, luider en/of langzamer wordt uitgesproken dan andere woorden. We hebben het effect van deze prosodische middelen onderzocht in twee domeinen van taalbegrip: het begrijpen van zinnen en het begrijpen van verwijzingen naar voorwerpen. In hoofdstuk 2 hebben we ons gericht op de rol van prosodische grenzen bij het begrijpen van zinnen. In hoofdstuk 4 hebben we gekeken naar de rol van accenten bij het begrijpen van verwijzingen naar voorwerpen. In hoofdstuk 3 hebben we de gecombineerde invloed van prosodische grenzen en accenten bij het begrijpen van zinnen onderzocht.

In het onderzoek naar zinsbegrip heeft men veelal gebruik gemaakt van lokaal ambigue zinnen. Deze zinnen kunnen, tot een bepaald moment in de zin, op twee verschillende manieren worden geïnterpreteerd. Een disambiguerend woord in de zin maakt dan duidelijk wat de juiste interpretatie moet zijn. Zinnen (1) en (2) hieronder zijn voorbeelden van lokaal ambigue zinnen die gebruikt zijn in hoofdstuk 2 en 3.

1. De leerling bekende de leraar te hebben gespiekt.
2. De leerling bekende de leraar te hebben opgesloten.

Deze twee zinnen zijn identiek tot het laatste woord, het tweede werkwoord (*gespiekt/opgesloten*). In (1) is dit werkwoord (*spieken*) intransitief; je kunt niet *iemand* spieken. Hierdoor kan *de leraar* geen lijdend voorwerp zijn van *spieken* en moet *de leraar* dus meewerkend voorwerp zijn van het eerste werkwoord in de zin, *bekende*: de leerling bekende het spieken aan de leraar. In (2) is het tweede werkwoord (*opsluiten*) verplicht transitief; je moet *iemand* opsluiten. Daarom moet *de leraar* lijdend voorwerp zijn van *opsluiten*: de leraar werd opgesloten. Hierdoor kan *de leraar* in dit geval geen meewerkend voorwerp zijn van *bekende*.

Voordat het disambiguerende woord (hier: het tweede werkwoord) in de zin wordt gehoord of gelezen, kun je de zin tot dan toe al op één van de twee manieren een eerste interpretatie geven (bv. *de leraar* is wel of niet het meewerkend voorwerp van *bekende*). Als de eerste interpretatie niet overeenkomt met het disambiguerende woord van de zin, leidt dit tot verwarring. In leesexperimenten leidt die verwarring ertoe dat lezers dit woord langzamer gaan lezen. Met zulke leesexperimenten hebben onderzoekers aangetoond dat de eerste interpretatie van een lokaal ambigue zin kan worden beïnvloed door factoren die verband houden met de grammaticale structuur van de zin, de betekenis van de woorden in de zin en de context van de zin. Leesexperimenten zijn echter niet geschikt om de factor prosodie in gesproken taal te onderzoeken. Om het begrip van gesproken zinnen te bestuderen, is het meten van 'event-related potentials' (ERPs) een uitstekende methode. ERPs zijn hersenpotentialen die gerelateerd zijn aan een bepaalde gebeurtenis, bijvoorbeeld een bepaald soort woord in een zin. ERPs maken het mogelijk om te bestuderen hoe luisteraars zinnen verwerken, op het moment dat ze de zin horen.

Enkele ERP-studies hebben eerder gekeken naar de rol van prosodische grenzen in zinsverwerking, bijvoorbeeld een studie van Steinhauer, Alter en Friederici (1999). Zij maakten gebruik van Duitse zinnen met dezelfde grammaticale structuur als (1) en (2). Ze veronderstelden dat als er een prosodische grens is na *bekende*, deze grens dit woord zou scheiden van *de leraar* en daarmee zou aangeven dat *leraar* niet het meewerkend voorwerp van *bekende* is. Daarom zou deze prosodische grens zin (2) gemakkelijker maken en zin (1) juist moeilijker maken. Ze vonden inderdaad dat luisteraars, in zinnen zoals (1), verwerkingsproblemen kregen (duidend op verwarring) op het tweede werkwoord (*gespiekt*) als er een prosodische grens kwam na het eerste werkwoord. Deze verwerkingsproblemen werden in het ERP zichtbaar als een N400 (duidend op problemen om het woord in de zin in te passen) en een P600 (duidend op een herverwerking van de zin). Deze ERP componenten worden beschreven in hoofdstuk 1. Bovendien vonden zij een brede positieve ERP component op het moment dat luisteraars de prosodische grens zelf verwerkten. Zij noemden dit een closure positive shift (CPS).

In hoofdstuk 2 rapporteren we een studie over hetzelfde onderwerp, waarin enkele tekortkomingen van de hierboven beschreven studie worden aangepakt. Het eerste werkwoord in (1) en (2) (*bekende*) is een zogenoemd subject-control werkwoord. Dit betekent dat het onderwerp (in het Engels: subject) van dit werkwoord (*leerling*) ook geïnterpreteerd moet worden als het onderwerp van het tweede werkwoord in de zin (bv. *gespiekt*); de leerling heeft gespiekt. Daarentegen is het eerste werkwoord in de voorbeelden (3) en (4) (*adviseerde*) een zogenoemd object-control werkwoord.

3. De arts adviseerde de vrouw te slapen.
4. De arts adviseerde de vrouw te ondersteunen.

Adviseerde is een object-control werkwoord, omdat het (meewerkend) voorwerp (in het Engels: indirect object) van dit werkwoord geïnterpreteerd moet worden als het onderwerp van het tweede werkwoord in de zin. In (3) is *de vrouw* het meewerkend voorwerp van *adviseerde* en het onderwerp van *slapen*; de vrouw moet slapen. In (4) is de situatie gecompliceerder omdat het meewerkend voorwerp van *adviseerde* (aan wie geadviseerd wordt) impliciet wordt gelaten. Deze impliciete persoon is echter ook diegene die de vrouw moet ondersteunen. Zinnen met subject- en object-control werkwoorden lijken oppervlakkig dan wel erg veel op elkaar, maar hun onderliggende structuur is verschillend. Hoewel beide typen zinnen in het experiment van Steinhauer en anderen (1999) voorkwamen, hebben ze de resultaten van alle zinnen samengenomen. In dit proefschrift hebben we deze twee typen zinnen afzonderlijk onderzocht, waarmee we konden laten zien dat ze verschillend verwerkt worden.

Ten tweede hebben Steinhauer en zijn collega's niet onderzocht hoe luisteraars deze zinnen interpreteren zonder prosodische grens. Daarom konden zij niet bepalen of een prosodische grens deze interpretatie verandert. In hoofdstuk 2 hebben we eerst de interpretatie zonder prosodische signalen onderzocht met een zinnen-invul-taak. Deelnemers kregen het ambigue deel van zinnen zoals (1) tot (4) te horen of te lezen (zonder het tweede werkwoord) en moesten de zinnen afmaken. Subject-control zinnen, zoals (1) en (2), werden vaker afgemaakt met een transitief werkwoord (zoals *opgesloten*), terwijl object-control zinnen, zoals (3) en (4), meestal werden aangevuld met een intransitief werkwoord (zoals *slapen*). Hierna rapporteren we in hoofdstuk 2 een ERP studie. In tegenstelling tot Steinhauer en anderen hebben wij niet alleen zinnen met een prosodische grens na het tweede werkwoord gebruikt, maar ook zinnen zonder prosodische grens. Voor de subject-control zinnen, zoals (1) en (2), vonden we verwerkingsproblemen (een N400) voor het intransitieve werkwoord (*gespiekt*) ongeacht of er een prosodische grens na *bekende* aanwezig was of niet. Dus, luisteraars interpreteren deze zinnen met en zonder prosodische grens in eerste instantie hetzelfde.

Voor object-control zinnen, zoals (3) en (4), vonden we ook verwerkingsproblemen voor een intransitief werkwoord (*slapen*), maar alleen wanneer er een prosodische grens aanwezig was na *adviseerde*. Zonder een prosodische grens, vonden we geen verschillen tussen (3) en (4). Luisteraars hebben dus geen duidelijke voorkeur voor één van beide interpretaties wanneer ze geen prosodische signalen krijgen, maar een prosodische grens zorgt ervoor dat er een voorkeur ontstaat voor een transitief tweede werkwoord, zoals in (4).

In hoofdstuk 3 hebben we onderzocht of niet alleen prosodische grenzen, maar ook accenten de interpretatie van zinnen kunnen beïnvloeden. We veronderstelden dat accenten, net als prosodische grenzen, ook woorden in zinnen op een bepaalde manier kunnen groeperen. Normaliter geeft een accent op een woord aan dat dat woord belangrijk of nieuw is in een zin en dus nadruk moet krijgen. Het antwoord in (6) is bijvoorbeeld een correct antwoord op de vraag in (5a), omdat het geaccentueerde woord JAN (accenten worden aangegeven met hoofdletters) *nieuwe* informatie is relatief tot de voorafgaande vraag.

5. a. Wie is er gevallen?
   b. Wat is er gebeurd?
6. JAN is gevallen.

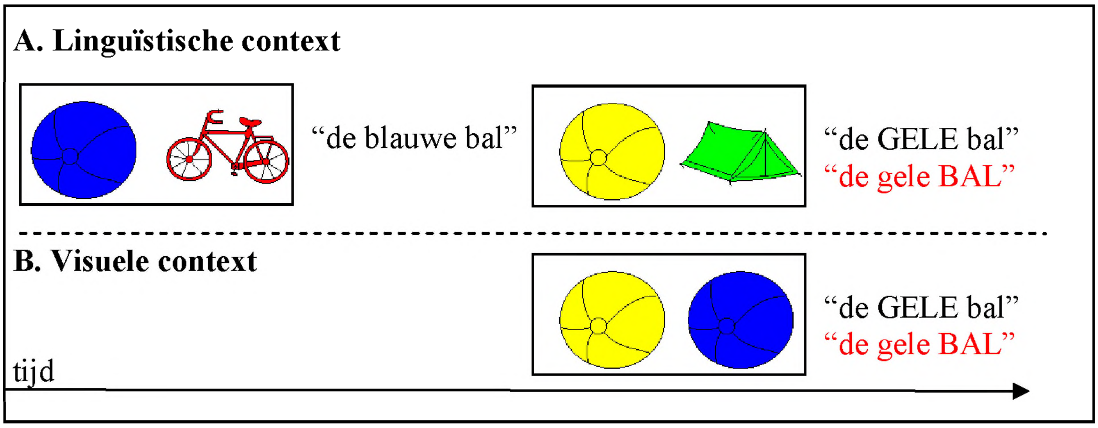
De nadruk die gegeven wordt door een accent kan zich echter ook uitbreiden naar aangrenzende woorden, als die gerelateerd zijn aan het geaccentueerde woord. Het antwoord in (6) kan ook een correct antwoord zijn op de vraag in (5b), hoewel alle woorden in (6) nu nieuw zijn, relatief tot de vraag. Blijkbaar kan het accent op *JAN* de nadruk leggen op alle woorden in de zin. Dat kan omdat *Jan* het onderwerp van *is gevallen* is. Op deze manier kunnen woorden gegroepeerd worden omdat ze door hetzelfde accent nadruk krijgen.

We hebben een ERP-studie uitgevoerd waarin we zinnen zoals (1) tot (4) lieten horen zowel met een prosodische grens na het eerste werkwoord als met een accent op het volgende zelfstandig naamwoord (*de leraar/de vrouw*). In combinatie met de prosodische grens benadrukt dit accent zowel het zelfstandige naamwoord als het daarop volgende werkwoord en groepeert deze twee woorden daardoor. In (2) en (4) verloopt deze groepering probleemloos, omdat het geaccentueerde woord (*leraar/vrouw*) het lijdend voorwerp is van het volgende werkwoord (*opgesloten/ondersteunen*). In (1) kunnen *leraar* en *gespiekt* echter niet samen worden gegroepeerd, aangezien *leraar* geen relatie heeft met *gespiekt*. De groepering door het accent leidde inderdaad tot een sterk verwerkingsprobleem op het werkwoord *gespiekt* (N400 en P600). In (3) is *de vrouw* syntactisch niet gerelateerd aan *slapen*, maar als we naar de betekenis van de zin kijken, moet *de vrouw* geïnterpreteerd worden als het onderwerp van *slapen*: de vrouw moet slapen. In de ERPs zagen we dat het verwerkingsprobleem op *slapen* verdween. Hieruit konden we concluderen we dat het accent op *de vrouw* een sterke aanwijzing had gegeven om deze woorden (*vrouw* en *slapen*) te groeperen en dat dit heeft geleid tot een interpretatie van de zin die “goed genoeg” was: de interpretatie is dan voornamelijk gebaseerd op de betekenis van de zin, en niet op de syntactische structuur.

Voor object-control zinnen hebben we in hoofdstuk 2 aangetoond dat de prosodische grens een bepaalde interpretatie van de zin kan induceren. In hoofdstuk 3 bleek dat accenten de interpretatie van zinnen ook kunnen bepalen, door de woorden in de zin op een bepaalde manier te groeperen. Toekomstige studies zullen de relatieve rol van prosodische grenzen, accenten en hun combinatie in dit proces moeten achterhalen. Hoofdstuk 2 heeft laten zien dat on-line studies, die tijdens het verwerken van de zin meten (zoals ERP studies), en off-line studies, die achteraf meten (zoals zinnen-invul-taken), soms tot verschillende resultaten kunnen leiden. Dit betekent dat on- en off-line processen wellicht door verschillende factoren beïnvloed worden. Bovendien bleek uit beide hoofdstukken dat de interpretatie van subject- en object-control zinnen aanzienlijk verschilt. De corpusstudie in paragraaf 3.6 van hoofdstuk 3 suggereert dat dit verschil gerelateerd kan worden aan de structuur van de zinnen waarin subject- en object-control werkwoorden meestal voorkomen. Tot slot hebben we de bevinding van de CPS-component in het ERP, als reactie op de prosodische grens zelf, gerepliceerd. In paragraaf 2.4 rapporteren we enkele analyses die aantonen dat dit een robuuste ERP component is.

In hoofdstuk 4 hebben we ons gericht op de rol van accenten in het domein van referentiële communicatie. Dit gebied omvat uitingen die ergens naar verwijzen, bijvoorbeeld een voorwerp in de wereld. Voor luisteraars lijkt het gemakkelijker om het beoogde voorwerp te midden van andere voorwerpen te identificeren als de spreker een contrast maakt met de andere voorwerpen. Als sprekers bijvoorbeeld naar een auto verwijzen, kunnen ze deze contrasteren met andere auto's in de omgeving (we noemen dit de visuele context). Als de andere auto’s andere kleuren hebben, kunnen ze dit contrast met een accent benadrukken: *Ik bedoel de RODE auto*. Een andere mogelijkheid is om de beoogde auto te contrasteren met een auto die eerder werd genoemd in het gesprek (we noemen dit de linguïstische context): *Jij hebt een gele auto, maar ik heb een RODE auto*. Onze voornaamste onderzoeksvraag was hoe luisteraars accenten verwerken die een contrast uitdrukken in deze twee soorten context.

We hebben een ERP studie uitgevoerd met een eenvoudige opzet. Deelnemers zagen steeds twee gekleurde voorwerpen, gevolgd door een uiting die verwees naar één van deze voorwerpen. In de linguïstische context werd steeds een contrast gecreëerd met de voorafgaande uiting. Een reeks van twee uitspraken als *de blauwe bal, de gele bal* creëerde bijvoorbeeld een contrast met kleur (zie Afbeelding 1A). We veronderstelden dat luisteraars in dit geval een accent op de kleur zouden verwachten (*de GELE bal*, zie Afbeelding 1A), terwijl een accent op het voorwerp (*de gele BAL*) zou leiden tot verwerkingsproblemen. In de visuele context werd een contrast gecreëerd tussen de twee voorwerpen die gelijktijdig te zien waren (bijvoorbeeld een gele bal en een blauwe bal, zie Afbeelding 1B). Onze verwachtingen voor wat betreft de verwerking van accenten waren hier vergelijkbaar. Merk op dat in een 'verkeerd' geaccentueerde uiting (aangegeven in rood in Afbeelding 1) altijd het accent ontbreekt op het ene woord (bijvoorbeeld de kleur: *gele*), aangezien dit contrastieve informatie is, en er een overbodig accent is op het andere woord (bijvoorbeeld het voorwerp: *BAL*), aangezien deze informatie niet contrastief is. We hadden twee verschillende hypothesen met betrekking tot de resultaten, de Ontbrekend Accent Hypothese en de Verkeerd Accent Hypothese. De Ontbrekend Accent Hypothese voorspelde dat alleen ontbrekende accenten zouden leiden tot verwerkingsproblemen, terwijl de Verkeerd Accent Hypothese voorspelde dat zowel ontbrekende als overbodige accenten verwerkingsproblemen op zouden leveren.



Afbeelding 1 Voorbeeld in de linguïstische context (venster A) en in de visuele context (venster B). In de linguïstische context contrasteert de kleur van het genoemde voorwerp (*geel*) met de kleur die in de vorige uiting wordt genoemd. In de visuele context contrasteert de kleur van het genoemde voorwerp (*geel*) met de kleur van het andere voorwerp dat gelijktijdig zichtbaar is. De 'correct' geaccentueerde uitingen zijn in zwart gedrukt en de 'verkeerd' geaccentueerde uitingen in rood.

In de linguïstische context vonden we evidentie voor de Ontbrekend Accent Hypothese; alleen ontbrekende accenten (waar ze wel verwacht werden) leidden tot verwerkingsproblemen (een negatieve component in het ERP) en overbodige accenten niet. Blijkbaar is het belangrijk voor luisteraars dat *nieuwe* informatie geaccentueerd wordt, omdat dit de informatie is waar ze hun aandacht op moeten richten. Voor in de context *gegeven* informatie maakt het echter niets uit of het wel of geen accent heeft, omdat deze informatie al bekend is.

In de visuele context waren de resultaten minder consistent. Wanneer de kleur de contrastieve informatie was (zoals in Afbeelding 1B), bevestigden de resultaten de Ontbrekend Accent Hypothese, net als voor de linguïstische context. Wanneer het voorwerp de contrastieve informatie was (bv. een gele bal en een gele hoed) vonden we verwerkingsproblemen wanneer het kleurwoord geen accent had. Deze resultaten zijn mogelijk vertekend door het feit dat de kleurinformatie hier overbodig is (beide voorwerpen zijn immers geel). Een accent op de kleur geeft wellicht aan dat er toch een reden is om de kleur te noemen. Over het algemeen is het patroon van resultaten voor de visuele context minder duidelijk dan voor de linguïstische context. Dit is in overeenstemming met een studie op het gebied van taalproductie van Pechmann (1984), waaruit bleek dat sprekers geen accent gebruiken om contrasten in de visuele context te markeren maar wel om contrasten in de linguïstische context te markeren. In paragraaf 4.6 van hoofdstuk 4 rapporteren we een klein productie-experiment om te kijken of contrasten in de visuele context wel tot accenten leiden als ze onder de aandacht van de spreker worden gebracht. Dit bleek niet het geval te zijn. Wellicht heeft de visuele context alleen invloed op de productie en/of de perceptie van accenten in een situatie met meer interactie tussen de gesprekspartners.

Tot slot een methodologische kwestie. Hoewel in ERP onderzoek geen extra taak vereist is, maken de meeste ERP studies toch gebruik van een taak. In de experimenten in dit proefschrift hebben we geprobeerd om met behulp van de taak (en de instructie) de luisteraars zich zoveel mogelijk te laten concentreren op het doel dat zij in de dagelijkse taalverwerking ook hebben. In hoofdstuk 2 en 3 instrueerden we hen om de zinnen te proberen te begrijpen, en in hoofdstuk 4 moesten ze het voorwerp vinden waarnaar de uiting verwees. In sommige gevallen kan dit hebben geleid tot subtielere en/of andere effecten dan in andere ERP studies, waar men een taak gebruikte die minder generaliseerbaar was naar situaties buiten het laboratorium (zoals het beoordelen van de prosodie).

Uit dit proefschrift kunnen we concluderen dat prosodie (in de vorm van prosodische grenzen en/of accenten) een belangrijke rol speelt in twee verschillende domeinen van taalverwerking. Ten eerste gebruiken luisteraars zowel prosodische grenzen als accenten om woorden in een zin te groeperen en daarmee de interpretatie van de zin te bepalen. Ten tweede vinden luisteraars het belangrijk dat nieuwe (en contrastieve) informatie door sprekers wordt geaccentueerd.

Dankwoord

De titel van dit proefschrift suggereert dat taalbegrip vergeleken kan worden met de uitvoering van een toneelstuk, waarin verschillende factoren (zoals prosodie) een rol spelen en verschillende 'acteurs' (zoals prosodic breaks en accenten) ten tonele gevoerd kunnen worden. Ik heb geprobeerd in dit proefschrift te achterhalen wat voor een soort karakter prosodie in dit toneelstuk speelt en hoe en wanneer de specifieke acteurs hun rol vervullen. Dit proefschrift zelf is misschien ook wel te vergelijken met een toneeluitvoering. Beiden zijn namelijk niet in je eentje te voltooien. Zowel voor als achter de schermen, zowel direct als indirect, hebben zeer veel mensen hun medewerking aan dit project verleend. Deze wil ik hierbij graag bedanken.

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Curriculum Vitae

Sara Bögels werd geboren op 12 juli 1982 in Cuijk. Ze bezocht het Merlet College Land van Cuijk en ontving haar VWO diploma in 2000. In datzelfde jaar begon ze aan de opleiding Psychologie aan de Radboud Universiteit Nijmegen. In het derde jaar van deze opleiding koos ze voor de richting Ontwikkelingspsychologie, waarbinnen ze in het vierde jaar stage liep op een school voor speciaal basisonderwijs en een scriptie schreef over de cognitieve ontwikkeling van jonge kinderen onder supervisie van prof. dr. Marianne Riksen-Walraven. Daarnaast werkte ze als werkgroepbegeleider bij statistiek- en methodecursussen. In 2004 studeerde ze cum laude af. Daarna begon ze aan de internationale onderzoeksmaster Cognitive Neuroscience in Nijmegen en koos voor de specialisatie Psycholinguïstiek. Ook werkte ze in die tijd als student-assistent op het Max Planck Instituut voor Psycholinguïstiek in Nijmegen in de groep van prof. dr. Anne Cutler. In 2006 studeerde ze cum laude af na een onderzoeksstage en scriptie bij prof. dr. Herbert Schriefers over de rol van prosodie in zinsbegrip. Dit onderzoek zette zij voort en breidde zij uit vanaf 2007 toen zij begon als promovendus aan het Donders Institute for Brain, Cognition and Behavior (Centre for Cognition). Haar project werd begeleid door prof. dr. Herbert Schriefers, prof. dr. Wietske Vonk en dr. Dorothee Chwilla en dit proefschrift is het resultaat. Tijdens haar promotietraject heeft zij onderwijs gegeven aan psychologiestudenten (waaronder vier maal als zelfstandig docent de cursus Toegepaste Onderzoeksmethoden) en de basiskwalificatie onderwijs (BKO) behaald. In 2010 werd haar een Rubicon subsidie (NWO) en een Niels Stensen Stipendium toegekend. Vanaf april 2011 gaat zij daarmee voor een jaar onderzoek doen naar de verwerking van common ground informatie door luisteraars in het lab van prof. dr. Simon Garrod aan de Universiteit van Glasgow in Schotland.

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